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Abstract

The pygmy hippopotamus (*Choeropsis liberiensis*) is an elusive and endangered species that only occurs in West Africa. Not much is known about the habitat preference and activity pattern of this species. We performed a camera trapping study and collected locations of pygmy hippo tracks in Taï National Park, Ivory Coast, to determine this more in detail. In total 1785 trap nights were performed with thirteen recordings of pygmy hippo on ten locations. In total 159 signs of pygmy hippo were found. We analyzed the habitat preferences with a normalized difference vegetation index (NDVI) from satellite images, distance to rivers and clustering using GIS. The NDVI indicates that pygmy hippos are mostly found in a wetter vegetation type. Most tracks we found in the first 250 m from a river and the tracks show significant clustering. These observations indicate that the pygmy hippopotamus prefers relatively wet vegetation close to rivers.
With camera trapping the activity pattern of this species was studied. We found that the pygmy hippo has a cathermal activity pattern, active during day and night. Our data provide no evidence that the pygmy hippo is avoiding the presence of the leopard (*Panthera pardus*). There was however not enough data to confirm this finding statistically. A lot of other animal species have been recorded by camera trapping as well but no relation with the pygmy hippo has been found, again probably due to small sample sizes.
The information gathered in this study helps for a better understanding of the ecology of this elusive and endangered animal. With GIS it is possible to model the habitat of the pygmy hippo. This is important for the conservation management of the pygmy hippopotamus in the future. Several suggestions have been made for future research.

Keywords: pygmy hippopotamus, habitat preference, GIS, activity pattern

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1. Introduction

The pygmy hippopotamus (*Choeropsis liberiensis*) is listed by the IUCN as a critically endangered species (IUCN 2009). Pygmy hippos occur in Liberia, Guinea, Ivory Coast and Sierra Leone. In Nigeria sightings have been reported but it is now believed that they are extinct in that region (Mallon et al. 2011). In the Ivory Coast, the pygmy hippos are restricted to the Guinean Forest zone between 7˚ 25'N in the north and 4˚ 18'W in the east (Roth et al. 2004). This study on the pygmy hippo has been performed in Taï National Park, situated in the South West of Ivory Coast.

The official number in the wild is estimated by the IUCN at a few thousand individuals, however the exact number of pygmy hippos is unknown. During the last decades several estimates have been made. The overall trend is that the population in the wild is declining. Estimates for the Taï National Park were fewer than 12,000 individuals in 1982 and 5,000 in 1997 (Roth et al. 2004). In 2011 the estimated number of pygmy hippos in Taï National Park was around 2,000 (Mallon et al. 2011). In 1982 densities are estimated at 3.6 hippos/km^2 with peaks at 7.6 hippos/km^2 in primary forest and 2.9 hippos/km^2 in secondary forest. In 1997 estimates were between 0.8-2.5 hippos/km^2 (Roth et al. 2004).

Compared to his bigger cousin, the common hippopotamus (*Hippopotamus amphibius*) pygmy hippos are considerably smaller. The weight of an adult pygmy hippo varies between 180-270 kg versus the 2000 kg of the common hippo. Pygmy hippos are more pig shaped, have relatively longer legs, smaller heads and a more sloping profile (Eltringham 1999). These are all adaptations for moving through the dense vegetation of the rainforest. The pygmy hippo lives solitary, except when a female has a young or during an oestrus period around the time of mating (Roth et al. 2004). During the day they hide in swamps, wallows or hollows under trees next to rivers. During their movement through the forest they mark their territories by wagging their tail while defecating (Eltringham 1999).

In the wild pygmy hippos are known to eat ferns, tender roots, grasses, herbs, stems and leaves of young trees, vegetables and fallen fruit. Also they have been observed to take cassava and the tender shoots of young rice plants from plantations and farms at the forest edge (Bülow 1987; Eltringham 1999; Hentschel 1990).

Pygmy hippos are mainly threatened by poaching and habitat destruction. Deforestation is a major problem with about 10 million hectares of the original forest lost in West Africa. Around 80% of all the forest is transformed into an agricultural forest mosaic (Norris et al. 2010). The protected area of Taï National Park is now the main remaining continuous block of rainforest in West Africa with an area of 4570 km^2 (Mallon et al. 2011). The primary reason for the deforestation is caused by the huge increase of the human population in the area. The Southwestern part of Ivory Coast had been spared until recently because it was very remote and scarcely inhabited. Since the government decided to build roads in 1968, it opened the access for people to migrate and start agriculture and logging. Agriculture is mainly practiced as a slash and burn practice. During the 70's even more people were moving from the Sahel, and later on refugees from Liberia (Chatelain, Gautier, & Spichiger 1996). Increase in human pressure means a higher demand for bush meat. Even with the ban on hunting in Ivory Coast, poaching is a great threat for wildlife in the protected areas (Caspary 1999; Hoppe-Dominik et al. 2011).

Not much is known about pygmy hippo ranging patterns, home range size or territorial behaviour. One earlier study using radio collars estimated the female home ranges at 40-60 ha and males 150 ha. The home range of males consists of two or three female home ranges. According to the same study male pygmy hippos cover a distance of two kilometres a day and female on average 900 m (Bülow 1987; Roth et al. 2004). Pygmy hippos do not abandon their home-ranges (Roth et al. 2004).

Also little is known about the relation of the pygmy hippo with other species that co-habit the primary forest of Taï National Park. In the Guinean forest zone there are a lot of other animal species occurring like forest elephants (*Loxodonta cyclotis*), forest buffalo (*Syncerus caffeanus*), bongo (*Tragelaphus eurycerus*), giant forest and red river hogs (*Hylochoerus meinertz-hageni* and *Potamochoerus porcus*), and forest duikers (*Chephalophus* spp.). All feed on dycotyledons and their fruits and could therefore increase competition (Roth et al. 2004). Alternatively species can be profiting from each other, for example by eating leftovers from fruits eaten by pygmy hippo or be more alert on predators when foraging together. This is known from monkeys species associations living in Taï National Park (Höner, Leumann, & Noë 1997; Wolters & Zuberbühler 2003) but no research has been done on other species yet.

The main habitat of pygmy hippos consists of primary rain forest close to rivers, streams and Raphia palm tree swamps (Bülow 1987; Hentschel 1990; Roth et al. 2004), despite the fact that moving around for adult pygmy hippos in swamps is difficult and noisy (Bülow 1987) . Their habitat is a patchwork of permanent rivers, temporary water courses, gallery forests, as well as patches of forest of different size and vegetation structure. The habitat characteristics which appear to be most important are the presence of small streams with submerged trees, root hollows, swampy depressions, and the size and density of ground vegetation (Roth et al. 2004). The habitat of pygmy hippos must provide well hidden and protected places for resting, calving, feeding and hiding of the calves. The activity of the pygmy hippo is believed to be at its peak in the early evening, but the pygmy hippo is active during the day and night as well (Bülow 1987).

The main focus of this study is to define more specifically the habitat preference of the pygmy hippo. For conservation purposes it is important to expand current knowledge. Previous studies worked with radio collaring of the animals (Bülow 1987). In this study five animals were followed, four females and one male for a period of five months in Azagny National Park in the south of the Ivory Coast. Recent camera trapping is on-going in Sierra Leone and in Liberia. First results are promising, 45 events in 682 trap nights in Sierra Leone (Conway 2009) and 3 events in 14 trap nights in Liberia (Collen et al. 2008).

In this study camera trapping and collecting locations of tracks, dung and feeding places is used to analyze the habitat preference. These data will be used by analyzing the pygmy hippo sighting locations with the NDVI index, distance to rivers and clustering. The whole research period falls within the rainy season, March-July. Therefore, the weather conditions are relatively constant; however, differences between rainy and dry seasons cannot be studied.

My hypothesis is that pygmy hippos indeed occur more in wetter areas than dry areas and close to rivers. They need these places for hiding and feeding. This was already suggested in literature but has never been studied in this way. Pygmy hippos will be found more in areas with a higher NDVI value that indicates a wetter forest type (Mayaux 2000). The distance to rivers will be relatively short as the pygmy hippo prefers wetter areas and uses rivers as hiding and resting places. When pygmy hippos are concentrating around wet vegetation and close to rivers, it is to be expected that the found tracks form clusters.

With camera trapping the date and time of the photos were stored, which allows analysing the activity pattern of the pygmy hippo. Every animal that passes a camera is likely to be recorded. These data can also be used to determine the relationship of the pygmy hippo with other species.

Animals in the rainforest all have a different activity pattern depending on their strategy of survival. Mammals in rainforests are largely nocturnal (van Schaik & Griffiths 1996). In earlier studies it is found that mammals smaller than 3 kg can have any activity pattern, diurnal, nocturnal or cathemeral (active during day and night). Animals bigger than 100 kg always have a cathemeral activity pattern (van Schaik & Griffiths 1996). Large animals need to forage more than the twelve hour period of a diurnal of nocturnal activity pattern. Terrestrial species are predominantly cathemeral (van Schaik & Griffiths 1996). Based on these general trends I expect pygmy hippos to be cathemeral as well.

The only natural predator of the pygmy hippo is the leopard (*Panthera pardus*) (Hentschel 1990). Pygmy hippos and leopards are both predominantly active during the night (Jenny 1996; Roth et al. 2004). There is proof of a juvenile pygmy hippo being caught by a leopard, of 215 feces samples taken by Hoppe (1984) one pygmy hippo was found (Hoppe-Dominik 1984; Jenny 1996). Nothing is known about the interaction of the activity pattern of the pygmy hippo and his main predator.

According to what is known in literature I expect that pygmy hippos do not avoid the leopard by adapting its activity pattern, there is no proof of adult pygmy hippos being caught by a leopard.

With camera trapping a relationship between the pygmy hippo and those species also caught on camera can be expected, no study has been done yet on this relationship. I expect to see a relationship with those species eating the same food as pygmy hippos such as fruits of dycotyledons.

2. Material and methods

2.1 Study Area

The research was conducted in Taï National Park in the Southwest of Ivory Coast (Figure 1). The park has a core zone of 330.000 ha protected as a UNESCO heritage site. The geographical location is in the west of Ivory Coast, between 5° 15' to 6° 07'N and 6° 54' to 7°25' W. There is a buffer zone around the Taï National Park of 66.000 ha to serve the needs of the local people and protect the core zone from disturbances (Bartelink 1995). It is the largest remaining continuous block of rainforest in West Africa that once stretched out from Togo, Ghana, Ivory Coast, Liberia, and Sierra Leone to Guinea-Bissau also known as the Guinean zone (IUCN 2007). Over 50 species of higher plants are endemic to the Taï region and 54% of all plant species only occur in the Guinean zone (Poorter & Bongers 2004). The forest of Taï National Park can be divided into two main types, in the south of the park moist evergreen with leguminous trees, and in the north moist semi-evergreen forest (IUCN 2007). The primary forest area where the research has taken place is dominated by *Eremospatha macrocarpa* and *Diospyros manii*. The area is flat (160-240 m) and drained by a network of small rivers. Apart from a specific flora in swampy areas along the streams, the vegetation structure is quite homogeneous (Jenny 1996).

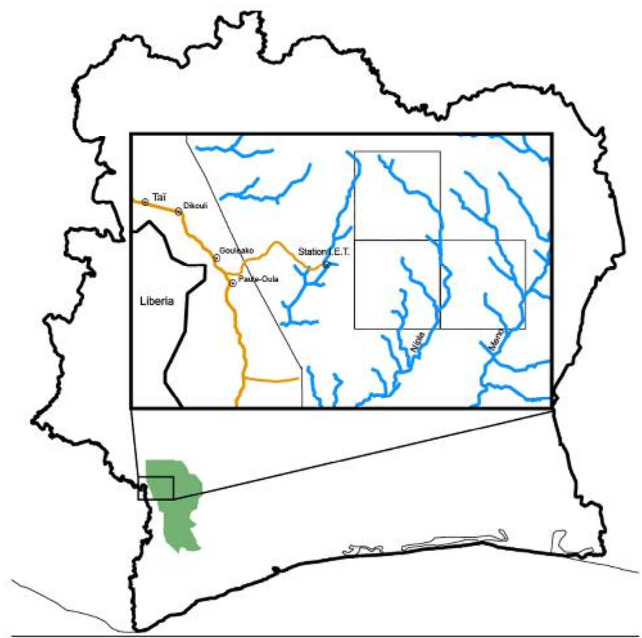


Figure 1: Position of Taï National Park within the Ivory Coast and an overview of the study area including the 6x6 km sample areas.

Annual precipitation ranges from 1700 mm in the north to 2200 mm in the south. The wet season is from March/April until July and a short period from September to October (IUCN 2007). In the past around 80% of the forest in Ivory Coast has been deforested, that has led to a great increase in total evapotranspiration (total amount of plant transpiration and soil evaporation) and especially in the north of the park dry winds come in the dry season because of the deforestation of the area around (IUCN 2007).

For the pygmy hippo research only a small part of Taï National Park was used (Figure 1.). This area was chosen for this study because it is easily accessible from the village of Taï. For several decades there has been a research station from which research has been done on for example chimpanzees (Pan troglodytes), several monkey species and leopards (Boesch et al. 2008; Jenny 1996; Leendertz et al. 2010; Range & Noë 2002; Wolters & Zuberbühler 2003). There are three groups of chimpanzees habituated and several groups of monkeys, which are followed every day to study their behavior. The presence of a research area has a protective effect on the animal densities by discouraging the local human population of trespassing the area. The presence of a research area is proven to be a strong predictor of animal population densities especially for threatened or over-harvested species (Campbell et al. 2011). From earlier research it is known that this place harbors relatively high densities of pygmy hippos. (Bülow 1987; Hentschel 1990; Hoppe-Dominik et al. 2011; Wild Chimpanzee Foundation 2008).

2.2 Camera trapping

The main survey of the pygmy hippos was done by camera trapping. Twenty cameras of the type Bushnell Trophy Cam 5.0 Megapixels with 2 GB memory cards were used. This camera has a detection range and infrared flash of 45 feet (14 m). On the backside of the camera there is a color viewer for viewing of the pictures and adjust the settings. The trigger time of the camera is 1.2 seconds and has a wide detection angle. This camera performs best on short distances according to a comparison with other cameras (www.trailcampro.com). All these features make this a very suitable camera for this study.

The home range of the pygmy hippos is thought to be around 50-150 ha (Hentschel 1990; Bülow 1987; Roth et al. 2004). On average 1-2 cameras were placed per home range of 1.5 km^2. We decided to place one camera per potential home range just as Conway (2009) suggested, blocks of 6x6 km were made for 18 cameras (Figure 2). This is a tradeoff between size of terrain, number of cameras and what is practically possible. In case of camera failure or theft there were two spare cameras available for this study.

There have been other studies with camera traps studying pygmy hippos (Collen et al. 2008; Conway 2009) in other parts of West Africa, in Liberia and in Sierra Leone on Tiwai Island with a total of 682 trap nights over 4 sampling periods of two weeks. April Conway (2009) concluded that two weeks was sufficient for getting enough pygmy hippos on camera. Therefore, the advised three week period was used, 21 trap nights.

In advance it was very difficult to determine were exactly to put the sampling rounds. On site the blocks of 6x6 km were drawn in ESRI ArcGIS 9.3.1 and the coordinates of the left corner of that rectangle were derived from that program. These coordinates were put in an excel sheet especially made to calculate the coordinates of each separate camera location. The coordinates were loaded on the GPS device (Garmin GPSmap 60 CSx) for use in the field. Once on the location a place was chosen within 100m, which was very likely to be visited by animals, preferably a trail or animal tracks.

The cameras were attached to a tree at about one meter above the ground, in a northern or southern direction to avoid the camera being triggered by the sun. The exact location is stored in the GPS device so that it could be retrieved more easily. This is all based on the protocol used by Collen et al. (2008), see Appendix 1. The cameras were retrieved with help of the GPS device in the same order that they were placed so that all cameras had the same number of trap nights. At the base camp, the cameras were reconditioned with new memory cards and newly charged batteries for the next camera trapping session. The data is downloaded into a computer according to the data collection protocol, see Appendix 2.

The sampling blocks were placed parallel to rivers so that a gradient from the river into the forest will be taken into account. This to see if there is an effect of the distance to the river on the occurrence of the pygmy hippo (Conway 2009). The exact place of the blocks and the placement of the cameras were done in the park. The first block was placed parallel on the western side of river Nipla. This was close to the base camp and easily accessible because of all the walking paths present. Most of the signs of pygmy hippo presence were present close to rivers, so we decided to do one period of sampling next to the river where it is most likely to catch a hippo on camera. Especially because the study was focused at the activity pattern, as much data as possible is needed. Placing the cameras in a stratified way provides less

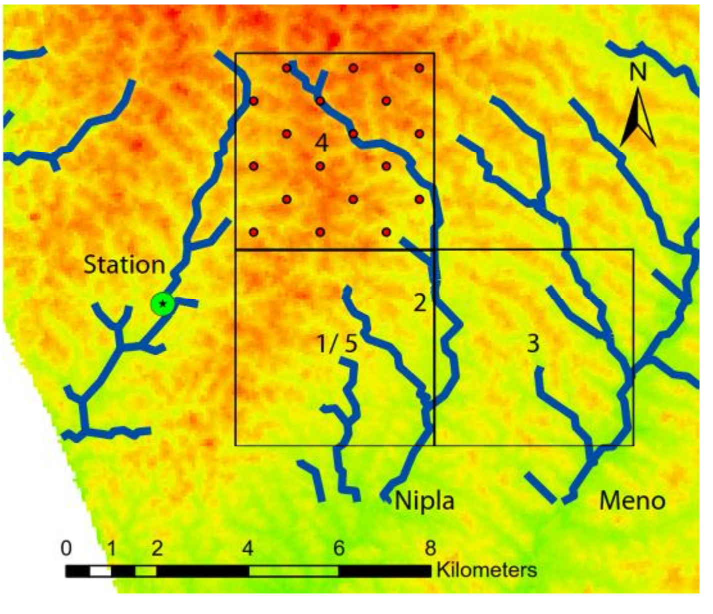


Figure 2: Position of the sampling blocks, numbered in chronical order. Round 4 shows the camera setup. Elevation is expressed with the colors red (high) to green (low).

data. For the second round, the settings were changed from picture into video. This is potentially better for animal species recognition (and good for promotional material, video material of this animal in the wild is rare). Unfortunately, another camera became unusable because a very large tree fell right on top of it. For the following sampling rounds, only 17 cameras were left. The number of pygmy hippos caught on camera was lower than expected, only five events for the second round. Additionally on some cameras, the memory cards of 2 GB were not sufficient to store all the video.

The third block was placed east of the Nipla, with the western border next to the first sampling block and the eastern border close to the river Meno. The fourth block was placed north of the first block, the west side still parallel to the Nipla. Because the first block did not work out very well we decided to do the fifth and last block in the same area as the first block. The total number of trap nights in those five sampling rounds was approximately 1785, on average 17 cameras out in the field for 21 nights.

2.3 NDVI

For the study area a normalized difference vegetation index (NDVI) was made. A NDVI is calculated with: NDVI=(α_{nir}-α_{vis})/ (α_{nir}+α_{vis}), where α_{nir} and α_{vis} represent the near infrared (0.8 μm,) and infrared, IR (0.6 μm). The NDVI is an index that can be used to correlate with certain physical properties of the vegetation, LAI index, fractional vegetation cover and biomass (Carlson & Ripley 1997). The wetter and swampy areas have a higher NDVI value than the dryer parts of the forest (Mayaux 2000).

As input for the NDVI index, Landsat TM satellite images with a resolution of 30 m were used. The images were made on March 3, 2003, which is during the dry season. This is one of the few available images with a low cloud cover. No newer images could be acquired because the budget was limited. The images with both the near infrared and the visible red were imported into ESRI ArcGIS 9.3.1 and a layer with the NDVI values of every raster cell of 30x30 m is calculated.

With only the NDVI index it turned out to be impossible to make a clear distinction in different vegetation types. The difficulty of the classification of the different vegetation types out of satellite images in the Taï area is already stated by (Bartelink 1995). There is a distinction between really wet, swampy areas and dryer parts of the forest. Therefore, by looking at the relative difference in NDVI values it will be possible to see if the pygmy hippo prefers wet above dry habitats.

2.4 Collecting tracks

From the beginning, the number of camera trap events of the pygmy hippo was very low, only one event in the first sample period. That would be not enough for the initial plan to analyze the activity pattern of the pygmy hippo. To collect more data during the stay in Taï National Park also the exact locations of tracks, feeding sites and dung were collected. That data can be used for the determination of the habitat preference of the pygmy hippo, together with the locations collected with camera trapping of the pygmy hippos. The location data will be compared with the value of the NDVI index as described in the methods above. The tracks will be analyzed for clustering and on the smallest distance to nearby rivers (Figure 2.).

Apart from the dataset of all the found pygmy hippo locations (H1) also random sets of locations were made in exactly the same area (R1 & R2). Also a set of random points of the routes we walked in the forest was made, RW1. This is to see if there is a difference between random data and the found data and the walked routes through the forest. Not all the locations were found at random, some of them were found by deliberately walking next to the rivers. To exclude the effect of having many locations next to rivers, most of the tracks were found by walking next to rivers, a separate dataset is made with all tracks not found by walking next to a river (HNR). At last, there is a dataset with all the locations found by walking directly next to a river (HR). The different NDVI values of the locations where pygmy hippo tracks are found are compared with sets of random points in the same area.

The distance to rivers was calculated with ArcGIS 9.3.1. First, a map with all the potential rivers in the area was made. The map was derived from an elevation layer, presuming all the water flows to the lowest point. The rivers begin at the point where the discharge area is at least 27 ha (300 units of 30x30 m). Compared with the rivers seen in the field and on the map it is a good size and on approximately the real location.

The last thing analyzed on the location data is to test for clustering. If the tracks cluster it could mean that you have a single animal on its territory. On the map pygmy hippo tracks are not distributed evenly and clustering can be expected (Figure 3.).

With ESRI ArcGIS 9.3.1 it is possible to do a multi-distance spatial cluster analysis. This tool uses the Ripley's K function. With the analysis, the average distance (K) is calculated of respectively 1-25 nearest neighbors. K is the number of neighbors at a certain distance. When the observed K is higher than the expected K, it is an indication of clustering.

2.5 Pygmy hippo versus other species

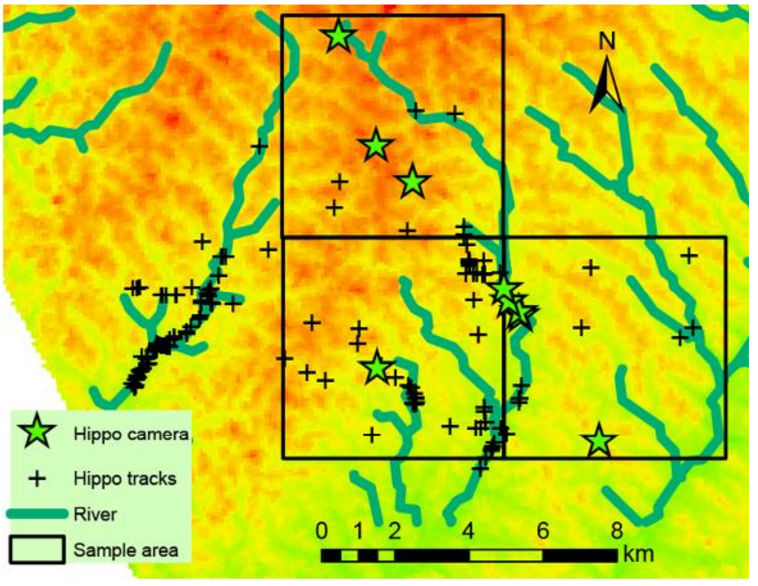
Besides the relation with the leopard, I decided to analyze the relation with other species caught on camera as well. There is not much known about the competition between pygmy hippos and other species. Duikers for example eat similar food as pygmy hippos; fruits and foliage (Hentschel 1990; Newing 2001) so these species could be possible competitors. Also not much is known about the competition between duiker species (Newing 2001).

To see if there is a possible relationship between the pygmy hippo and other species you can have a look at which species were recorded on the same camera as the pygmy hippo. After that, you can determine if they are occurring relatively more on the same camera location or relatively more on other locations.

Species with a very low number of events were filtered out of the list with recorded animal species. All are potential competitors for food or a predator of the pygmy hippo and/or have sufficient number of camera trap events. First, the number of locations was counted that the species is recorded on the same location as the pygmy hippo. In addition, you can calculate what the expected number of cameras is that a species was recorded on the same spot. With a Chi-square test it is possible to test whether the expected value differs significantly from the observed value. Thus investigate if certain species occur significantly more on the same spot as the pygmy hippo.

3. Results

3.1 Habitat preference



On the map in all the observed pygmy hippo tracks can be seen (Figure 3). These are all the locations where we found dung or footprints, and locations where the pygmy hippo is caught on camera. This is the basis for the upcoming analyzes on the habitat preference.

Figure 3: All the found pygmy hippo locations, footprints, dung and feeding sites. The stars are the locations were the pygmy hippo was recorded on camera

3.1.1 NDVI

First, the data was tested for normality, this was not the case. In addition, several attempts to transform the data into a normal distribution did not succeed. So the Wilcoxon rank sum W test with continuity correction was used for further analysis.

Between both the random data sets (R1, R2) there is no significant difference (Table 1,2). But between the random sets of locations (R1) and the pygmy hippo locations (H1) there is a significant difference in NDVI value (p<0.0001). The average NDVI value of H1 is higher than R1 which means a wetter vegetation type is preferred (Mayaux 2000). Also there is a significant difference between tracks found by walking next to the river or by not deliberately walking next to a river.

Between the random datasets and HNR there is no significant difference. This suggests that when pygmy hippos are not walking next to rivers they walk randomly through the forest, without preference for wet or dry vegetation.

The NDVI values between where we walked (RW1) differ significantly from where we found the pygmy hippo tracks. This can be expected because pygmy hippos were mostly found next to rivers. The same accounts for the difference between HNR and H1.

Table 1: Wilcoxon rank sum test results

Comparison:	P value:
R1 vs R2	P=0.8768
R1 vs H1	P<0.0001
R1 vs RW1	P=0.3383
RW1 vs H1	P=0.0027
HNR vs R1	P=0.3444
HNR vs HR	P<0.0001
HR vs H1	P=0.012

Table 2: Average NDVI values

Type	Mean
R1	0.3998
R2	0.4022
H1	0.4146
RW1	0.4057
HNR	0.4059
HR	0.422

3.1.2 Distance to rivers

The distances of every dataset were categorized into classes of 250 m from the nearest river. Also the total area per class is calculated. In the end the average number of tracks found per km^2 is calculated to adjust for area size, this is done for R1 and H1. When separated in classes it is possible to see the distribution from close to a river and far away. With an average distance it is difficult to see a gradient (Figure 4.). To test if the pygmy hippo tracks and dung are more likely to be found next or close to rivers than can be expected in a random pattern a Chi-square test is used. With H1 as observed and R1as expected there is a significant difference (χ^2= 324.6944, P<0.0001, df=9, n=20). The data is also tested without the separation of the data in classes. With the Wilcoxon rank sum test on H1 and R1 there is also a significant difference P<0.0001.

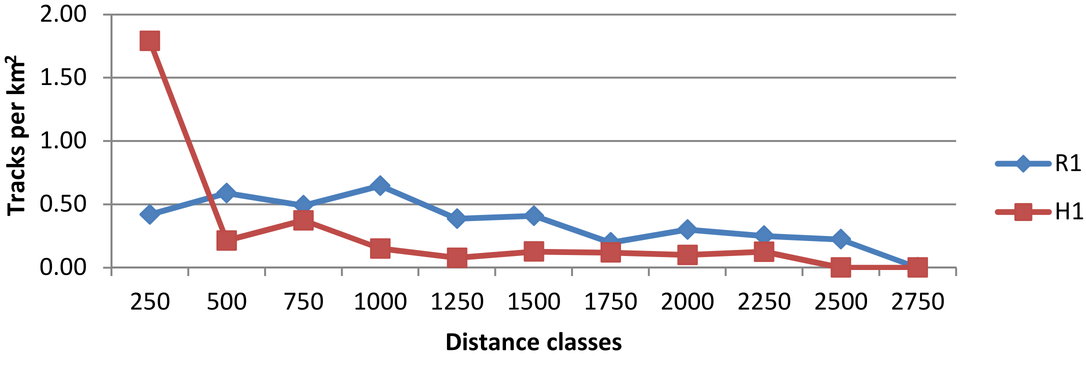


Figure 4: Number of tracks per km² per distance class of 250 m, R1= random points in same area, H1=All hippo signs

3.1.3 Clustering

With ESRI ArcGIS 9.3.1 a multi-distance cluster analysis can be performed. The distance is calculated for subsequently one, two, three, until 25 nearest neighbors, this is the observed distance K. The expected K is the distance when points are homogeneously scattered in an area. In the end the difference between observed K minus the expected K is calculated.

In the random sets of locations (R1), the observed K is more or less the same as the expected K, the random locations were not clustered. However, with the other datasets the observed K is much higher than the expected K value (Figure 5). The hippo dung locations are significantly clustered, the random locations on the walked path cluster as well, but not as strong as the other datasets.

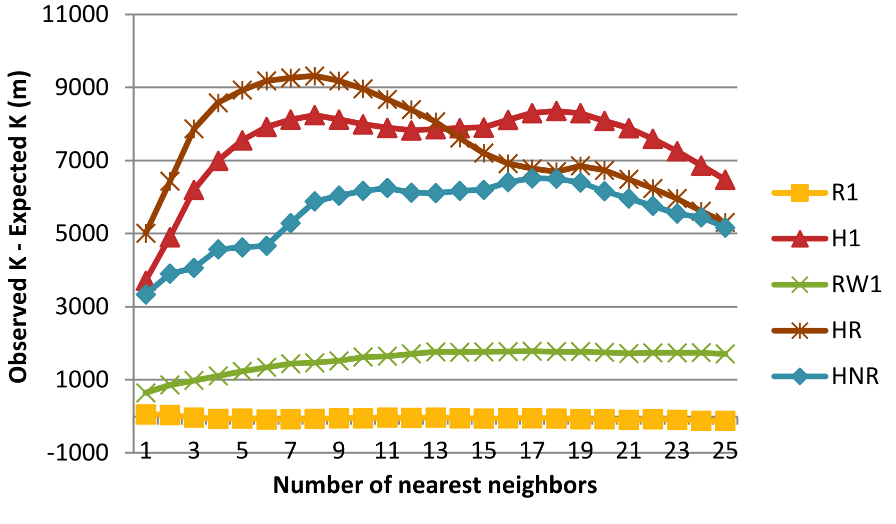


Figure 5: Observed minus expected K for HNR, R1, H1, RW1 and HR. R1= random points, H1=All hippo signs, HNR=Hippo signs found by not walking next to a river, HR=tracks found by walking next to a river RW1, random locations on routes walked.

3.2 Activity Pattern

The hypothesis was that pygmy hippos are active during the day and night, and thus show a cathemeral behavior. First impression is that the activity is indeed cathemeral, active during day and night. Unfortunately, again it was not possible to do statistical analysis. The number of events is very low, only thirteen in total in a period of about three months. The total number of events per day is very low. To really say something about the activity pattern of the pygmy hippo you should have a lot more data. This is also the reason why we decided to do more than only collecting camera trap data.

3.2.1 The Leopard

The second objective was to have a look at the activity patterns of the pygmy hippo and his predators, the most important predator besides the human is the leopard (Bülow 1987; Hentschel 1990). The hypothesis was that pygmy hippos adapt their activity pattern to avoid the activity of their predators.

This I wanted to test with the data collected with the camera traps, the total number of events for the leopard is nine and for the pygmy hippo thirteen (Figure 6). Not as much as we expected, rule of thumb is that at least 20 observations are necessary to do a statistical sound analysis. Because there is a low amount of data, the recorded events were counted for every six-hour periods. In the beginning of the day, the number of events is similar but after 12:00, there is a big difference. This is also tested with the Spearman rho test p=0.789, N=4. The activity pattern of the leopard does differ from that of the pygmy hippo.

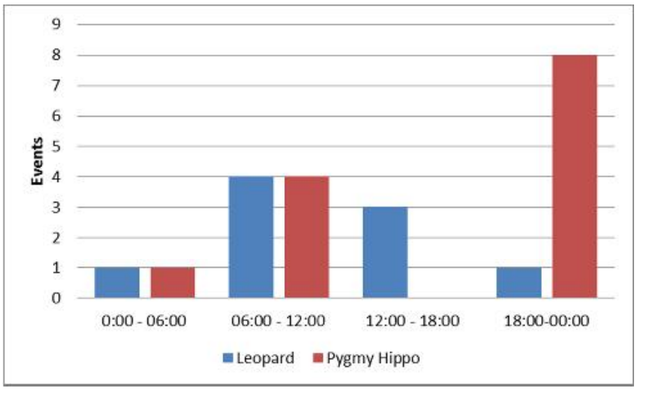


Figure 6: Number of events of the leopard and pygmy hippo per six-hour period.

The leopard is not recorded on camera between 19.00-03.00 but according to Jenny (1996) leopards in the Taï National Park leave 98% of their markings during the night. So taken together, this and the small amount of events the camera trapping data found is not likely to be representing the real activity pattern of the leopards in Taï National Park. Pygmy hippos have a peak activity around 16.00 until 23.00 (Bülow 1987). That seems to be according to the previous observations done. This has been done by tracking five individuals via radio telemetry in Azagny National Park, a swampy area in the South of Ivory Coast.

Between individual leopards the prey preference differs, old and young, male or female have a different preference of prey (Jenny 1996). In another study were the dung of leopards in the Taï region is examined on prey species only once a young pygmy hippo was found out of a total of 215 samples taken in one year. The diet of the leopard mostly exists of duiker species, about 40% (Hoppe-Dominik 1984). Most likely leopards do not attack adult pygmy hippos because they are too big, only the young ones are in danger. On the camera traps, only adult hippos were recorded.

3.2.2 Pygmy hippo in relation to other species

For every species, the number of camera locations is counted and how many of those locations they share with the pygmy hippo. The pygmy hippo is recorded on ten of the 81 camera locations. Together with the known proportion of camera locations of any other species it is possible to calculate what the expected number of cameras is that a certain species is caught on camera together with the pygmy hippo. Then you have the proportion in which you can expect the species to be recorded on the same spot (Table 3).

A Chi-square test was done to determine if the observed and expected values differ significantly. This is done for every species separately, with df=1, n=2 and critical value of 3.84 at the p=0.05 level. For every species, the calculated χ^2 is lower than 3.84 and thus the H0 hypothesis that observed and expected are the same is not rejected.

This means that there is no clear relationship, between the separate species and the pygmy hippo caught on the same camera on the same location. The chimpanzee has never been on camera on the same location as the pygmy hippo. This could be an indication that they are avoiding each other and/or using a different part of the forest, unfortunately there is not enough data to draw a conclusion.

Table 3: The observed and expected number of locations for several species, total camera locations is 81 and pygmy hippo locations 10. Critical χ^2=3,84 (df=1, p=0.05).

	Maxwell Duiker	Brooke Duiker	Zebra Duiker	Chimpansee	Sooty Mangabey	Leopard	Forest Elephant
#Camera locations	72	61	16	10	53	9	3
Same as Hippo	8	7	2	0	7	2	1
Expected	8.89	7.53	1.98	1.23	6.54	1.11	0.37
χ^2=	0.09	0.04	0.00	1.23	0.03	0.71	1.07

4. Discussion

The main goal of this study was to increase knowledge about the habitat preference of the pygmy hippo. On the one hand the results confirm mostly what has been suggested in earlier research, pygmy hippos prefer primary rainforest close to rivers and swampy areas (Eltringham 1999; Roth et al. 2004). On the other hand, this study can be seen as a pilot study that contributes to the development of future research. In addition, other research methods were used than in the past, which possibly gives new opportunities. Additional data collection will be going on soon in Taï National Park, and will hopefully confirm the findings presented here.

My first hypothesis was that pygmy hippos occur more in wetter areas than dry areas and close to rivers. At locations where pygmy hippos signs were found the NDVI values were higher than random locations in the same area. Higher NDVI values indicate a wetter vegetation type (Mayaux 2000). Pygmy hippo signs were found mostly within 250 m of a river. I also expected the tracks to cluster around those swampy areas and close to rivers. Indeed the found tracks of pygmy hippos are clustering significantly.

Besides the habitat preference also the activity pattern was studied. My first hypothesis for the activity pattern was that pygmy hippos are cathemeral. Pygmy hippos indeed seem to be cathemeral, active during day and night. Most of the activity is during the early night, but unfortunately there is not enough data to verify this and make a strong statement. The second hypothesis was that pygmy hippos do not change their activity pattern to avoid the main predator the leopard. There is not enough data to verify if this is indeed the case. Still there were difference found, during the early night the pygmy shows more activity than the leopard.

The relations with other species were also studied, I expected to see for species with a similar diet a positive association. No relation can be found between the locations were pygmy hippos were found and other species recorded on the same location. The differences between the observed and expected number of similar camera trap locations were small.

In total, we found 159 tracks in an area of more than 100 km^2, over a period of 3-4 months. For the habitat preference, it was enough to do an analysis but could have been much better with more data over a longer period. When you look at the difference between the pygmy hippo tracks found by not walking next to the river and random taken points there is no significant difference in the pattern. However, there could still be an underlying pattern not observed with this type of analysis. Therefore, it could be that this pattern is related to certain fruit trees, plant communities (assuming those are not randomly located) or in different seasons. Peaks in fruiting occur mainly in the long dry season (November-March), leaf flushing is peaking then as well but continues into the wet season (Anderson et al. 2005). What the effect of that is on the habitat preference is unknown, but looking at food preference this could make a difference. More research is needed to study the effect of seasons on the habitat preference of the pygmy hippo.

The GPS data collected of the pygmy hippo tracks were not collected in a systematic way. All the tracks encountered were taken into account. Placing and retrieving the cameras took a lot of time so there was not enough time to do this in a systematic way. In this way as much data as possible is collected. For future research it would be better to collect the tracks by walking in transects. However, this is difficult in a closed forest and will give less data, it would be better to collar pygmy hippos and follow them in real time. Not only can you then see where they spend their day but it will then also become possible to study their activity pattern in detail, despite the fact that the number of individuals will be low (Noss et al. 2003). Unfortunately, this was not possible in this study because of budget constraints preparation time and legislations.

In some areas a lot of tracks and in other areas a relatively low amount of tracks were found, for example in the Taï Chimpanzee Project (TCP) area (Anderson et al. 2005). In the first place this is because of the clustering but this could suggest also that pygmy hippos do avoid the (regular) presence of humans. In the research area there is no hunting on pygmy hippos, but there is a lot of hunting pressure on other animals. This could have an effect on the pygmy hippo as well. When the pygmy hippos are directly confronted with human presence, they will run away. On the other hand, tracks were found as close as 100 m from the basecamp. It is already noticed earlier that pygmy hippos are easily disturbed by humans (Bülow 1987). Not much is known about to what distance the pygmy hippo approaches the human settlements. It would be interesting to study the effect of human presence in future research. What level of human disturbance does the pygmy hippo tolerate?

The satellite images used were made in March 2003, seven years before the fieldwork and just before the period in the year that the research was performed. In March it is the dry season, and the research was done mostly in the rainy season. Unfortunately it was not possible to acquire newer images or from another period in the year. They were not available or too expensive. Besides that, many images have a high cloud cover. However, for the analysis the satellite images from 2003 should not be a big problem. In seven years, there have been no big changes in the area, no recent cutting of trees was observed. The biggest changes locally were trees that fell down after wind throw. With a resolution of 30 m that could influence the NDVI value of a particular pixel a lot, but in general the forest stays the same. The difference in NDVI value is studied not with the absolute value only the relative difference, and on average those possible errors would be of less influence of determining a wetter or dryer vegetation type.

The minimal size of the rivers is more or less on intuition but this never has been studied what the ideal size of river is. In addition, the level of the rivers fluctuates during the seasons, sometimes greatly during rain. It is not known if there is a relation between several river characteristics, like flow, width, depth and vegetation and the presence of pygmy hippo tracks.

The locations of hippo tracks do cluster. That pygmy hippo locations were mostly found within 250 m of a river can explain this. Besides that it could be that every cluster is one animal, or a female and male in their own territory. More research, with for example collaring of the animals can be used to find out more about the mechanism behind this clustering.

The activity pattern of the pygmy hippo is indeed cathemeral, but the number of events recorded is low. Also when comparing this with the activity pattern of the leopard this is a problem. To have sufficient data for analyzing the activity pattern at least twice as much camera trap nights are needed. Even then it would be difficult to prove that the activity pattern does differ and the reason why, difference could also be due to other factors.

Not one species is recorded significantly more on the same spot as the pygmy hippo or less as expected from the observed totals. There were differences but they are very small, it is better to look at not only the locations but also at the time in between the events. It could be that there are several days in between and then it is difficult to say if there is a relationship or not.

Camera trapping can be a way to study the pygmy hippo but many more camera trap nights are needed. Studying the habitat preference by analyzing NDVI values and distance to rivers can help modeling the habitat of the pygmy hippo. This can be extrapolated to the whole park or even other pygmy hippo suitable areas to predict how many pygmy hippos can potentially live in an area. However, for this more data is needed on population densities.

There are other methods to study the habitat preference of the pygmy hippo such as radio collaring. Using that method, a lot more data can be collected in number of locations and recordings of activity, which can be used to determine the activity pattern. Most of the tracks were found within 250 m of rivers and at certain parts, many tracks were found. Those places would be the ideal to catch a pygmy hippo for radio collaring them.

Taken everything together this study shows that much more research is needed. Not only on the activity pattern and habitat preference, but also on other aspects of pygmy hippo biology such as; reproductive cycles in the wild, genetics and the diet. All this information is needed to conserve this rare and endangered animal.

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Appendix 1. Camera trap programming and deployment protocol

Once the locations on the grid for the camera traps have been established and programmed into the GPS, navigate to the co-ordinates. The site for each camera should be within a 100m radius of the co-ordinate. The following procedure must then be followed to deploy the camera.

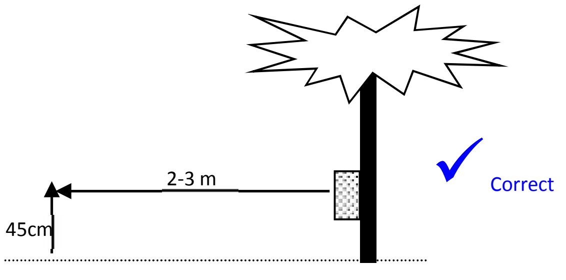
Steps 1-8:

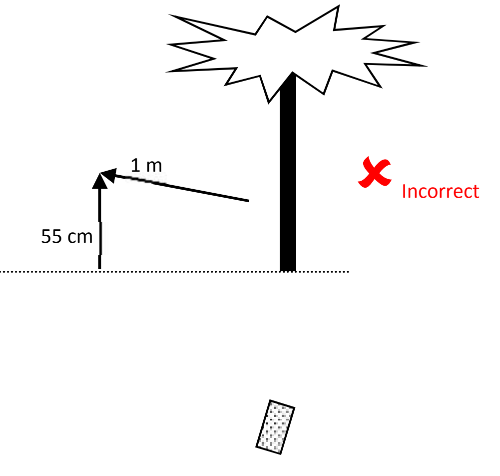
1. **Site Selection - consider the following:**
    - Animal Trail (recent - sign: dung/footprints)
    - Distance from trail (approx. 2-4 metres, no more than 6 m)
    - Tree dbh must be sufficiently big to hold camera, but small enough to ensure chain fits
    - Direction of camera: <u>Do Not</u> face East or West
    - Clear vegetation between site of camera and animal trail
    - Consider slope of ground between camera and animal trail
2. **Site Datasheet**
    - Write down GPS position of the camera location (try to allow up to 10 mins for GPS to settle)
    - Mark waypoint of exact location of camera in GPS
    - Use data sheet to record details of the camera set up and location
    - Use data sheet to describe the habitat around the camera
    - Note - distance between camera and trail to be completed in Step 5, once camera is mounted
3. **Prepare Camera**
    - Add batteries (check direction)
    - Add memory card: Ensure Camera # and Memory Card # are the same!
    - Ensure memory card case is bought back to HQ and battery box returned to camp to burn
4. **Programme camera**
    - Switch on camera
    - Press **MENU** to activate screen if it does not appear
    - Press **MENU** again to begin programming the camera settings - the setting to be changed will be flashing
    - Resolution will be the first setting and will be flashing
    - Press **OK**
    - Use up/down keys to change Resolution to High
    - Press **OK**
    - Camera will now be flashing
    - Press **OK**
    - Use up/down keys to change between Camera and Video to Camera
    - Press **OK**
    - # pictures will be flashing (#P)
    - Use up/down keys to change to 9
    - Press **OK**
    - Time Out will be flashing
    - Press **OK**
    - Use up/down keys to change to 1
    - Press **OK**
    - Date (date and time) will be flashing
    - Press **OK**

- Enter the time (using time shown on GPS)
- Enter minutes using up/down keys
- Press **OK**
- Enter hours using up/down keys
- Press **OK**
- Enter date – in the format month-day-year e.g. 1^{st} Feb 2008 as 02-01-2008
- Enter month using up/down keys
- Press **OK**
- Enter day using up/down keys
- Press **OK**
- Enter year using up/down keys
- Press **OK**
- DEL will be shown which means programming is complete
- Press **OK** twice
- Press **MENU**
- Check that the screen looks like this…..
- Remember to check the flash is on
- Turn camera **OFF**
- Close Camera

5. Mount Camera

- Strap camera to tree, camera sensor must be 45cm above the centre of the trail
- Check angle of camera (use stick to make camera 90^0 to the ground)
- Measure distance from camera to centre of trail (to complete the Site data sheet)





6. Crawl/Sensor Test

- Open camera, turn ON. Wait for screen to appear and press the red TEST button, close camera
- Crawl in front of the camera on the trail at the height of an animal (like a duiker) and check that that test light flashes. If light flashes camera is sensing your presence where you expect the animal to walk. If the light does not flash you may need to readjust the position (height and/or angle) of the camera
- Turn Camera OFF and ON again to end test phase

- Leave camera turned **ON** as next step secures camera closed!!!

7. **Securing camera (do as quickly as possible and without disturbing camera)**
    - Ensure rubber is tied tight around camera and tree for support
    - Lock camera to tree using the chain and padlock (padlock # should correspond to camera #)
8. **Final test**
    - Wait for blinking green light to stop
    - Before leaving do a final test to check that the camera is taking photos by breaking the sensor beam and observing the counter – smile!
    - When leaving the site DO NOT to walk in front of the camera!

Appendix 2. Data Collection protocol

After 21 days, cameras will be collected from the field. It is important that the data are retrieved in a specific manner. Note that the photos taken on each camera will be automatically assigned a file name by the camera (see 'picture code' in table below). The first photo taken on two different cameras will therefore be given the same automated code as a file name. It is therefore vital that each camera is kept separate, and pictures are recorded from the camera (and therefore geographic position) that they were taken at.

1. Remove the memory card from the camera and insert into card reader OR use the USB port on the camera, which can also be used to directly transfer from the camera to the computer.
2. Download the data from the camera to the specified file, according to the file structure shown below. Each camera has its own file, into which pictures should be downloaded. The name of the file is the same as the grid code that the camera was placed at.

File structure for download of photos

3. The following data should then be collated for each photo, in the Excel spread sheet.

Item	explanation
Code	The same code as the camera e.g. S1-1A-01
Picture code	The automated code assigned to the picture by the camera e.g. DSC_0001.jpg
Date of photo	Should be entered in the following manner: month-day-year
Time of photo	Be sure to use the 24 hr clock
Genus	First part of the scientific binomial of the Genus to which the species belongs e.g. Homo
Species	Specific name e.g. sapiens
Common name	e.g. Human
Person Identifying species	e.g. Ben Collen
Trap event number	These should be numbered sequentially (1, 2, 3...n). Pictures taken within 30 minutes of each other by the same camera should be considered the same 'trap event', and should therefore get the same trap event number.

4. Once all data are collated for that camera, and the photos stored in the correct file, repeat the process for the second camera.
5. Once all cameras have been downloaded, copy the data onto a CD to provide a back up.
6. Camera traps should then be maintained for storage or redeployment.
7. Once all photos have been downloaded and backup CDs made photos can be deleted from the memory cards and the cards stored for the next survey. NB: MAKE SURE ALL BACKUP CDs WORK BEFORE DELETING PHOTOS FROM MEMORY CARDS!!