

In search of the illusive Pygmy Hippo; Establishment of methods to determine population structure of Pygmy Hippos in Tai forest, and assessment of their role in seed dispersal

A research report by Mark van Heukelum



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Abstract

The pygmy hippopotamus is a rare and illusive animal; hardly any research has been performed on this species, while the current population has decreased over the last decades to proximately 3000 animals. Listed as *endangered* by the IUCN, the main threats to pygmy hippos are poaching and habitat loss. To be able to conserve this species from going extinct it is highly important to increase our knowledge on pygmy hippos living in the wild. Therefore, we performed a pilot study to establish methods that can determine the population structure (age and sex distribution), local densities and the role of pygmy hippos in seed dispersal. Camera traps and footprint measurements were used to estimate local densities and to count the number of males, females and juveniles. Footprints were measured and compared to a data set collected from pygmy hippos living in captivity, to see whether shape and size matches age and sex. Fecal samples were collected and analyzed for the identifiable seeds present and thereby unraveling the true role of pygmy hippos in seed dispersal. The camera trap method shows potential in determining the population size and structure, but it has to be improved in order to increase the amount of captures and to distinguish individuals. Generally, the camera trap results were insufficient to determine either population size nor structure, but it does show reduced activity between 12:00-18:00hr. The footprint method shows great potential not only for measuring population densities, but also in determining the percentage of juvenile pygmy hippos. In the Tai region one third of the footprints was juveniles, which suggests that the population is increasing. Furthermore, the footprints suggest that during their first year juvenile pygmy hippos barely move through the forest and that there appears to be a birth season at the end of the rainy season. More measurements, both in the field and in captivity, should be taken to strengthen this hypothesis. Feces analysis revealed that pygmy hippos do not contribute to the dispersal of seeds (<5mm); seeds do form a large part of the diet, but they are consumed as a whole, excreting only parts of the nutshell. In order to protect the pygmy hippo from going extinct more research on population size and structure, and reproductive biology is necessary, since so little is known about this rare animal.

Introduction

The pygmy hippopotamus (*Choeropsis liberiensis*) is a rare species found only in Western Africa (IUCN 2008). The species is occurring in Sierra Leone, Liberia and Cote d'Ivoire and a small population is found in the southern part of Nigeria. It has the status of an endangered species on the red list of the IUCN (IUCN 2008). In 1993 the Pygmy Hippo population in the wild was estimated at 2000-3000 individuals, and the IUCN red list states is that the current population trend is decreasing. However, more recent studies suggest that the number is underestimated and that the population size is between 10.000 and 15.000 animals, which was predicted based on the extrapolation of pygmy hippo tracks observed back in 1993 and 2002 (Roth *et al.* 2004). In the early 20th century pygmy hippos were captured by western hunters and shipped towards America and Europe (Appendix 4). One of the first documentations of pygmy hippos in captivity was in The New York Times in 1912, an article about the first living specimen captured in Liberia and brought to the Bronx Zoo in New York (The New York Times 1912). Today, almost all pygmy hippos living in zoos were born in captivity to zoo-born parents. As of October 2004 there are about 180 pygmy hippos in collections around the world (Smithsonian National Zoological Park, <http://nationalzoo.si.edu/Animals/AsianElephants/factpygmyhippo.cfm>). Although it is endangered in the wild, pygmy hippos breed well in zoos. Currently, not much is known about the state of the population and even less is known about the behavior and needs of the species itself (Collen *et al.* 2008). Poaching and habitat destruction are the main threats to the pygmy hippo population (Robinson 2009); bush meat is an important source of protein for rural people living around the rainforest, but moreover commercial hunting has a large influence on the wildlife of West Africa (Refisch and Koné 2005). Still, according to our local guide (personal communication field guide Donation) local small-scale poaching focuses more on small species like monkeys and duikers, because they are more common, easier to handle and for hunting large mammals large expensive bullets are needed. Probably of a larger influence is deforestation of the rainforest; over the last three decades deforestation in the western part of Côte d'Ivoire has been dramatic, not only decreasing the total forest cover, but also fragmenting the forest in small patches (Chatelain *et al.* 2010). For the pygmy hippo, that lives a solitary live and has a home range of 50-150km² (Roth *et al.* 2010), the loss and fragmentation of its habitat can have a great impact on the population size. It is therefore of great relevance that more research is done on pygmy hippos in the wild, in order to understand how they live and how to conserve this endangered species both in captivity as well as in the wild.

In this study, methods were developed to assess population structure (age and sex distribution), size and distribution by collecting footprints and using camera traps to compare local densities. To be able to translate footprint measurements to age and sex distribution reference footprints were taken from pygmy hippos living in captivity during a pilot study.

Also, the role of pygmy hippos in seed dispersal was investigated by collecting and analyzing fecal samples for the presence and identity of seeds. To be able to translate footprint measurements to age and sex distribution reference footprints were taken from pygmy hippos living in captivity during a pilot study.

Species description

Although the pygmy hippo has the appearance of a miniature common hippopotamus (*Hippopotamus amphibius*) the pygmy hippo shares only superficial similarities with its greater cousin, differing greatly in morphology, diet and behavior (Conway 2008). Morphologically it resembles more to a pig or a tapir, having relatively long legs, a small head and only moderately webbed toes, which makes the pygmy hippo more mobile and better adapted to the terrestrial environment compared to the common hippo (Robinson 2009). The body weight of a pygmy hippo ranges between 180-270 kg, males being slightly bigger than females. Their skin is highly sensitive to dehydration and sunburn, which is why they have to stay close to water. Because this species does not have temperature-regulating sweat glands the pygmy hippo produces a shiny red fluid through glands in their skin that is believed to provide protection from sunburn and infections (Conway 2008). Together with the common hippo, the Pygmy Hippo is an herbivore and falls under non-ruminating foregut fermenters (Claus *et al.* 2004). The diet consists of ferns, broad-leaved plants and fruits that fall on the ground on which they spend feeding 5-6 hours per day (Bülow 1988), but little is known about specific plant species (Roth *et al.* 2004).

The major threats to the pygmy hippo are poaching and the loss of habitat (Collen *et al.* 2008). According to Conway (2008) the meat of pygmy hippos has a high value and is therefore a prime target. Also, they are wary to people and sensitive to disturbance, which is why loss of habitat will force them to migrate. Still, according to our guides, pygmy hippos are not being poached upon severely in the Taï region. This was confirmed when we visited an area with several poachers' camps where barely any signs of monkeys and duikers were visible, but where we did find footprints and feces of pygmy hippos in the same density as other areas.

Area description

The research was performed in Taï National Park, Ivory Coast. It is situated in the south-west of the Ivory Coast at the border of Liberia. Although in the past there have been logging activities in the forest, the park exists mainly of primary rainforest, which means that the canopy is closed and bottom vegetation is limited. Still, due to succession old trees fall down regularly, creating gaps in which new vegetation can establish making the forest locally very dense. Taï National Park is divided into five regions, but research took place only in Taï, a region on the west side of the river *Mino* (Appendix 1). The wet season starts on average during May with a duration of proximately 4 months and will usually reach its top in July. Annual rainfall is about 2000 mm, with a peak of 500 mm per month during the wet season.

Objectives

- 1) Establishment of methods to assist in determining the geographical distribution of the pygmy hippo (*Choeropsis liberiensis*) across Tai National Park? Establishment of methods to determine the distribution in age and sex in the population?
 - Mapping of pygmy hippo distribution in a selected area of Tai National Park
 - Age and size estimation of the population in the study area by footprint analysis and camera trapping
- 2) Does the pygmy hippo play a role in seed dispersal of fruiting plants and trees?
 - Determining *the advantage for a seed of being* eaten by a hippo in terms of fertilization and distribution, by the use of seed marking, camera traps and experimental set ups

Hypothesis

Population structure and distribution

Research done in 1978-1984 suggested that the population size in the Ivory Coast was proximately 1100 animals, with a density of 3-4 animals/river km (Roth *et al.* 2004). Roth *et al.* (2004) investigated population density in Taï National Forest through questionnaires, interviews, radio telemetry and foot patrols in search of footprints and droppings, and they observed a drop in density to 1-2 animals/river km (0,8-2,5 animals/km²). By extrapolating the data they suggest that the total population size of pygmy hippos is greater than previously thought, but does not exceed 15000 animals. According to studies performed on similar animals species the percentage of juveniles (<2 yr) in a healthy and stable population can vary; the Baird's tapir (*Tapirus bairdii*), an animal with the most similar life history as the pygmy hippo, has an estimated yearly reproduction rate of 15-20% per year (Robinson and Redford 1991). However, large mammals like the black and white rhinoceros (resp. *Diceros bicornis* and *Ceratotherum simum*), African elephant (*Loxodonta Africana*), Indian rhino (*Rhinoceros unicornis*) and the hippopotamus (*Hippopotamus amphibius*) have an annual population growth of 5-15% (Conway and Goodman 1989; Rothley 2004; Owen-Smith 1988). Since not much is known about the reproduction of the pygmy hippo it's difficult to predict the annual growth rate. Still, because the average lifespan of a pygmy hippo (40-45 years) is more than a tapir (25-30 years) and less than the larger mammals (50-65 years) I expect the annual population growth for a stable pygmy hippo population to be 10-20%. The population in Taï National Park decreased between 1980-2002, but in the last few years several institutes are trying to improve the situation of Taï National Park. Therefore, it can be expected that the population is stable or slightly recovering, which means that the percentage of juvenile hippos is at least 15%.

Seed dispersal

Pygmy hippo's have a home range of 50-150 km² (Roth *et al.* 2004) and have not been seen captured on camera more than once a month (Conway 2008), which suggests that they occupy large areas and use various trails, but to be more precise it is of great relevance to look further into the distribution of the pygmy hippo. Together with the fact that pygmy hippo's were reported to eat fruit as part of their diet (Hentschel 1990), it can be expected that they play an important role in the dispersal of seeds. Since the hippo is a large animal and can consume large fruits and seeds, it can be assumed that this mechanism is especially important for trees with large seeds.

Hypothesis: The pygmy hippo plays an important role in the dispersal of (large) seeds

Seeds can have several advantages being eaten by animals, like being dispersed and fertilized by the feces. In a seed experiment, where I examine the effect of feces and hippo consumption on seed germination and growth, I expect that seeds that are consumed by a pygmy hippo will germinate faster compared to control seeds, but not necessarily grow faster. Also, I expect that the seed planted with hippo feces will grow faster than the control seed, but that it will not germinate faster. Finally, I expect that a seed that is both consumed by a pygmy hippo and planted with feces will both germinate and grow faster than the other compared to a control seed.

Hypothesis: Pygmy hippo consumption increases the germination of seeds

Hypothesis: Seeds planted with pygmy hippo feces will grow faster than other seeds

Hypothesis: Seeds that are consumed by pygmy hippos and planted with pygmy hippo feces will both germinate and grow faster than control seeds

Material and methods

Pygmy hippo population and distribution

To be able to say anything about the condition of the pygmy hippo population and to start conservation activities it is necessary to have an reliable estimation of the population size and distribution over time (Collen *et al.* 2008) and of the percentage of young pygmy hippos (0-2 year old) in the population. Therefore, this study tried to establish methods that will allow gaining more knowledge on population dynamics of the pygmy hippo using two methods; *footprint analysis* and *camera trapping*.

Pilot study

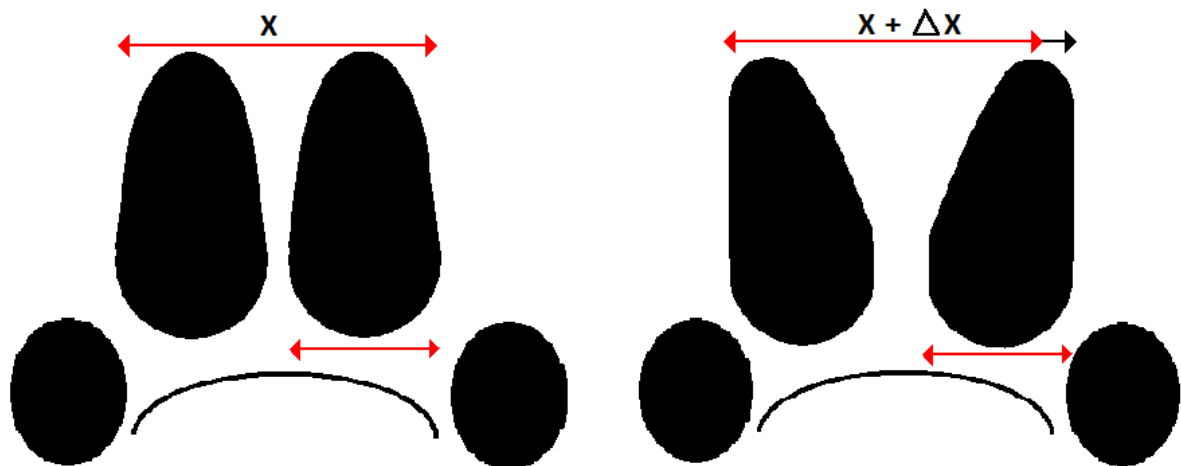
Footprints were taken of several pygmy hippos living in captivity to measure and compare differences in size between age and sex. Four adults and one juvenile of Blijdorp Zoo in Rotterdam and Burger's Zoo in Arnhem were sampled. Two wooden plates (60x60 cm) covered with clay were placed strategically near the entrance of the enclosure, on which the animals were lured with food. Clay was used to get a detailed print and to be able to take the prints for further research. As an alternative sand can be used to measure prints, which is more cheap, less frightening for the animals and more easy to apply. Several prints of male, female and young were taken and compared. The footprint of the young was measured at the age of 4 and 12 months, to relate footprint size to juvenile age.

Footprint analysis

The best way to obtain information on population size, structure and distribution of most rainforest species is to count droppings and/or footprint analysis, where age and sex distribution are determined based on the size of the footprint (Merz 1982). Juvenile pygmy hippos have a much smaller footprint size than adults, and based on the relation between age and size the age of a juvenile can be determined by its footprint. However, new born pygmy hippo's are hidden in dense vegetation for the first 3-5 months of their lives, so by the time they start to follow the mother the difference in footprint size might be less clear (Hentschel 1990). Still, our pilot study showed that the footprint of a juvenile pygmy hippo (age=4 months) is significantly smaller than its mother. Furthermore, according to the zoo a pygmy hippo will reach its adult-size at proximately 2 years old, so based on the percentage of footprints found corresponding to an age of 0.5-2 years old the total percentage of juveniles can be extrapolated. The population size can be estimated by determining individuals based on their footprint (Conway 2008). Skin crease, scars and malformations can be used to identify individuals and separate one print from the other. However, a pilot study reveals that it is difficult to distinguish clear footprints in clay, which indicates that footprints on forest soil might even be more difficult to distinguish. Still, the probability that a wild pygmy hippo has more distinct features is high, because it has a higher change of gaining foot 'damage'. Beside information on population formation gathering footprints, together with other indications of pygmy hippo presence, will show the distribution of pygmy hippo's over the park. I will use the *Shapiro-Wilk test* to test for a normal distribution and the *Wilson Score 95% confidence interval* (Brown *et al.* 2001) to calculate the range of the percentage of groups (male, female and juvenile) in the population. The *Wilson Score Interval* is very accurate when the amount of data is low.

Reference footprints are obtained from a set of different pygmy hippos living in zoos prior to the fieldwork in the Ivory Coast. Since the paw of a pygmy hippo exists of four separate and flexible toes, only the width of the front toes was measured (*figure 1a*), because the footprint size might differ depending on the way the paw is positioned (*figure 1b*). The two toes at the side are used for support and depending on the gradient of the forest floor they will leave a different print, which makes these toes not suitable for measurement. During this study only one front toe per footprint was measured, which is due to practical reasons, but is less accurate compared to measuring both front toes. This problem is further evaluated in the discussion. Footprints and other types of tracks will be gathered while traveling through Taï National Park, for they are easily detectable (Roth *et al.* 2004). All prints will be digitally recorded and information on size, location and distinct marks on the print (scars and malformations) noted. I will use a handheld GPS unit to obtain the exact location of the tracks, so the distribution of pygmy hippo's can be recorded.

Since the pygmy hippo is such an elusive animal the advantage of this footprint analysis is that the hippo itself does not have to be located/disturbed (Roth *et al.* 2004). A disadvantage is that it can only be used for rough estimations and that it might be hard to distinguish individual footprints under wet circumstances.



(a) Measurement front toe

(b) Measurement error

Figure 1. Since the toes of a pygmy hippo are flexible the toes have to be measured separately, because the distance between depends on the way the paw is positioned.

Camera traps

Another method that was used to estimate population size, structure and distribution is camera trapping. By modeling capture-recapture events population density can be analyzed. Compared to other methods used to detect and monitor rare wildlife species, camera trapping is one of the most effective methods to use (Vine *et al.* 2009; Trolle *et al.* 2008). Digital footage can provide much detail of an animal in terms of size, color pattern and body features, like scars and malformations, with which individuals can be distinguished (Royle *et al.* 2009; Karanth and Nichols 1998). However, like Conway (2008) I also experienced difficulty to distinguish individuals, because many hippos did not show clear body characteristics and the low number of trap events made it impossible to use this method.

We used 20 heat and motion detecting infrared cameras (Bushnell Trophy Cam 5.0 Mpx/Viewer). This type of camera was chosen because it performs better than other models on short distance, according to performance tests (www.trailcampro.com). The camera has a wide detection zone and a 1.2 second trigger. The home range of a male pygmy hippo is proximately 1,5km² (Hentschel 1990; Bülow 1987), while the home range of a female pygmy hippo is between 0.5-0.6 km² Roth *et al.*

	1	2	3	4	5	6
	RIVER					
A	X		X		X	
B		X		X		X
C	X		X		X	
D		X		X		X
E	X		X		X	
F		X		X		X

(2004), although it is not clearly stated how they estimated this size. Pygmy hippos do not obtain strict territories, therefore the home ranges of several males and females can overlap and a density of several individuals per km² can be observed (Roth *et al.* 2004). We chose to use the same set up like Conway (2008), which is agreed upon amongst pygmy hippo researchers. For this set up blocks of 36 km² are placed on predetermined areas, which in our case is alongside rivers flowing through Taï National Park. Eighteen cameras were subsequently placed in a standard grid, 2 km apart, in one block (*figure 2*).

Figure 2. One sample block of 36 km² (units of 1 km²), where every X represents a camera trap.

The sample areas were chosen on their geographic position (*figure 3*); area 1 is on the east side of the river *nipila* and within a research area, area 3 is between the rivers *nipila* and *mino* and area 4 is located further north within a research area and on a higher altitude. Area 2 is not a square grid like the other areas, but the cameras were placed strategically alongside the river Nipla, in order to test different settings and pygmy hippo behavior. I will use the *chi-square test* to test whether there is a difference in density among different areas. The exact trap location was reached using a handheld GPS unit. Once we reached the location we searched for an animal trail to place the camera within 100 m from the exact location, according to the camera trap protocol (*Appendix II*). The research team was split up in 2 teams, each placing 3 camera's a day. The time schedule for the experiments is presented in *table 1*.

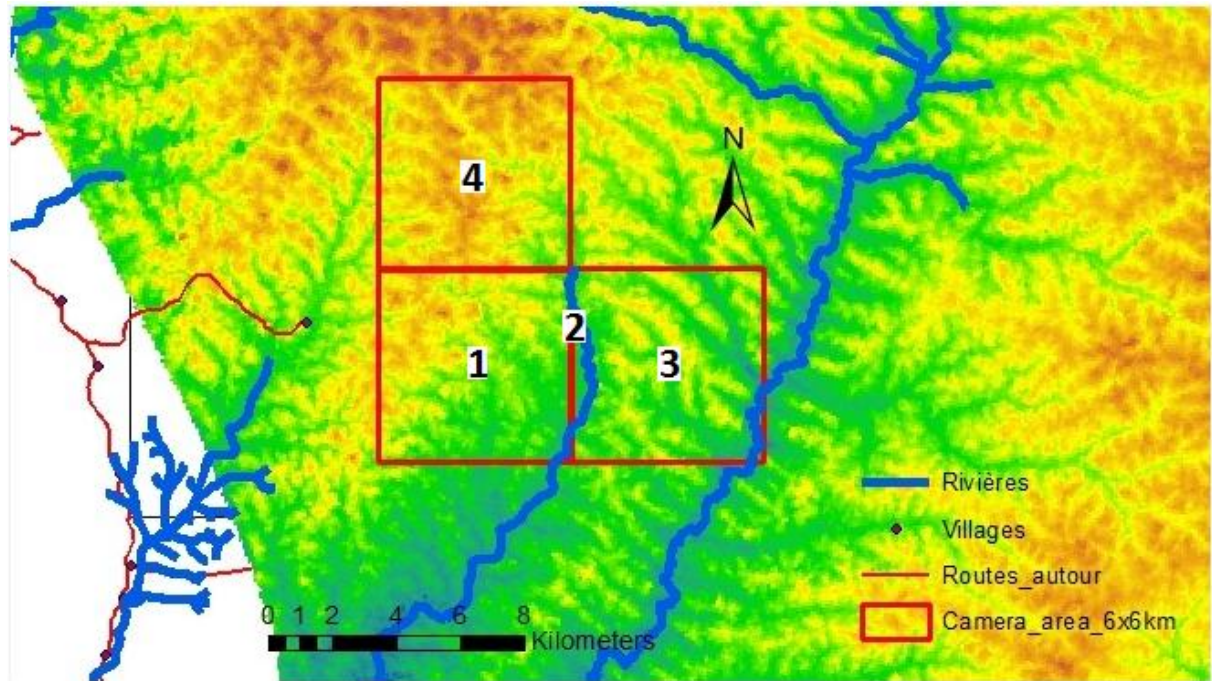


Figure 3. Map of research area on the east border of Tai National Park

Camera trapping has been used in many species density studies, but the sample time to leave cameras in the field varies among studies (Royle *et al.* 2009; Karanth and Nichols 1998; Trolle *et al.* 2008; Collen *et al.* 2008). A rule of thumb is, to detect a species with an expected occurrence of 1/1000 trap days it requires 3000 trap days of effort (O'Brien 2008). Conway (2008) had a detection of pygmy hippos of proximately 1/85 trap days, with a density of proximately 0.5 pygmy hippos per km². Using the rule of thumb she would need 260 trap days to detect a pygmy hippo (20 cameras x 13 days). The density in Tai National Park is been suggested to be proximately 1.2/km² (Roth *et al.* 2004), so in theory we would need then less trap days because the expected occurrence is higher. Still, Conway (2008) recommended a sample period of 3 weeks instead of 2, for 2 weeks did not deliver enough images. I therefore used a sample time of 21 days for 18 cameras, which accounts for 378 trap days per sample block. Although in theory this is far more than necessary, it increased the chance of recapturing individuals on camera. Since the risk of having a bad picture of an animal is quite high (for instant, the picture showing only part of an animal) we set the camera on taking three pictures per event, increasing the ability to determine the species caught on camera. Although small videos would have increased the identification process even more, the memory card does not have sufficient space to allow the camera function as a video camera for 21 days. Depending on the distance of the location, allocating and retrieving the camera's can take more or less time than expected. The next block can be sampled as soon as maintenance and preparation are done. During the sampling period the Camera Trapping Protocol will be used created and currently used by Collen *et al.* (2008), which is shown in Appendix 1. When the cameras are retrieved data will be stored according to the protocol, which is shown in Appendix 2.

Days	
3	Distributing camera's over the 36 km ² block.
21	Sampling period and recharging of batteries.
3-4	Retrieving cameras.
1-2	Maintenance of camera's and downloading data.

Table 1. Time schedule for 1 experiment period.

Seed dispersal

In nature many organisms live in some sort of partnership from which both species benefit, called a symbiosis. A clear example is the relationship between plants and animals, in which the plant supplies food (fruits or nectar) in 'exchange' of the distribution of seeds or pollen (Fragoso *et al.* 2003). The distribution of seeds can have several advantages, for instance the ability to invade new areas (Blake *et al.* 2009). Other advantages are the feces, in which the seed is being dispersed, that can act as a fertilizer or a decreased predation pressure (Fragoso *et al.* 2003). Since part of the diet of a pygmy hippo consists of fruits it is a potential seed disperser (Roth *et al.* 2004). To determine the role of the pygmy hippo in seed dispersal, the fruits that are part of the hippo diet have to be determined and to be quantified. When the type of fruits are determined, information needs to be gathered on the distance at which seeds are distributed (Blake *et al.* 2009) and whether they survive or even benefit on being consumed by the pygmy hippo (Jerozolinski *et al.* 2009). The distance can be measured by offering food to the pygmy hippo's that has been marked with small objects, which can be retraced after being excreted from the body. This way the distance from food take up and feces excretion can be measured. Whether fruits benefit from being eaten by pygmy hippo's can be measured by an experiment, in which germination time and grow speed of seeds are being measured for two factors; being eaten by a pygmy hippo or not, lying in a pile of dung or not (Fragoso *et al.* 2003).

Results

Camera trapping

During the research period 4 different areas were sampled with camera traps, of which one area was alongside the river *nipila* instead of in a grid (*figure 3*, no. 2). The first area (no. 1) was sampled two times, because the first time was seen as a test session and was sampled for two weeks instead of three, like all the other areas. In total there were 14 pygmy hippo trap events, which revealed 15 pygmy hippos (one event showing a mother and juvenile (+/- 1.5 yr)). Five out of 15 were male, five were female and 5 could not be identified in being male or female. Only at 1 incident it was possible to identify a juvenile (1.5-2 years old), because it was with her mother and it appeared to be smaller than the second pygmy hippo. On the other pictures it was hard to determine whether the individual was a juvenile, since I could not determine their size clearly. No young pygmy hippos (<1 year old) were captured on camera, which can back up the theory that pygmy hippos less than one year old barely move through the forest. The ratio male/female appears to be 1:1. However, with only 15 sightings it is hard to say anything about the population structure; the *Wilson score 95% confidence interval* calculated the range of the percentage of females in the population to be 23-76% ($n=10$). To reach a deviation of 5% from equality a sample size of $n=381$ is necessary.

Since the same set up was used in each 21 day session, the sample areas can be compared. In area 1 only one pygmy hippo was captured on camera, in area 3 there were three captures and area 4 had five captures. Area two had also five captures, but since a different set up was used the data can't be compared directly. Area 4 appears to have the highest pygmy hippo density, which is unexpected because I would expect that the density would be higher near a river. Still, the area contained many swamps and during the time of sampling the rainy season had started, creating better living conditions throughout the forest. Moreover, with the low amount of camera captures it is hard to draw any conclusions. There is no significant difference between the sample areas ($\chi^2=2.67$, $df=2$, $n=9$, $p=0.26$). To be able to say that the difference in pygmy hippo density between area 1, 3 and 4 is significant ($p<0.05$) the sample size should be 2.3 times larger ($\chi^2=6.86$, $df=2$, $n=21$, $p=0.045$).

Also for the activity pattern of the pygmy hippo it is hard to draw conclusions with the amount of data (*figure 4a*). Still, Conway (2008) suggests that pygmy hippos are less active during the mid-day (*figure 4b*) and when I look at the graph shown in *figure 4a* it does show an activity 'gap' between 12:00 and 18:00hr. When I divide the day in four parts of 6 hours (0-6hr, 6-12hr, 12-18hr and 18-24hr) and do a *chi-square test* were I test for an equal distribution of observations there is a significant difference in the amount of sightings (activity) during the day ($\chi^2=10$, $df=3$, $n=14$, $p=0.019$). When I run the same test, but now for no observations during the period 12-18hr and an equal distribution for the other periods there is no significant difference with the observations in the field ($\chi^2=4$, $df=3$, $n=14$, $p=0.14$). Therefore, it is likely that the activity of pygmy hippos during the period of 12-18hr is less than during the rest of the day. When I compare this to the data of Conway (2008) it does show a similar pattern (*figure 4b*). Pygmy hippos appear to be active from the evening around sunset (18:00hr) to late morning (12:00hr), resting during the afternoon (12:00-16:00hr). This is confirmed by the literature available on wild studies on pygmy hippos (Hentschell 1990, Robinson 2009, Appendix 4).

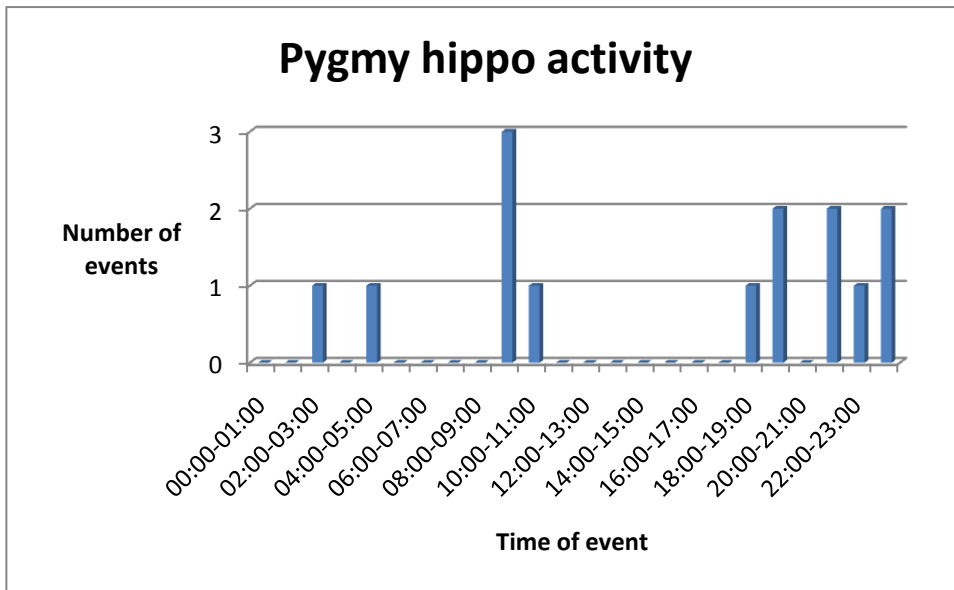


Figure 4a. Activity pattern of pygmy hippos captured on camera during the research period

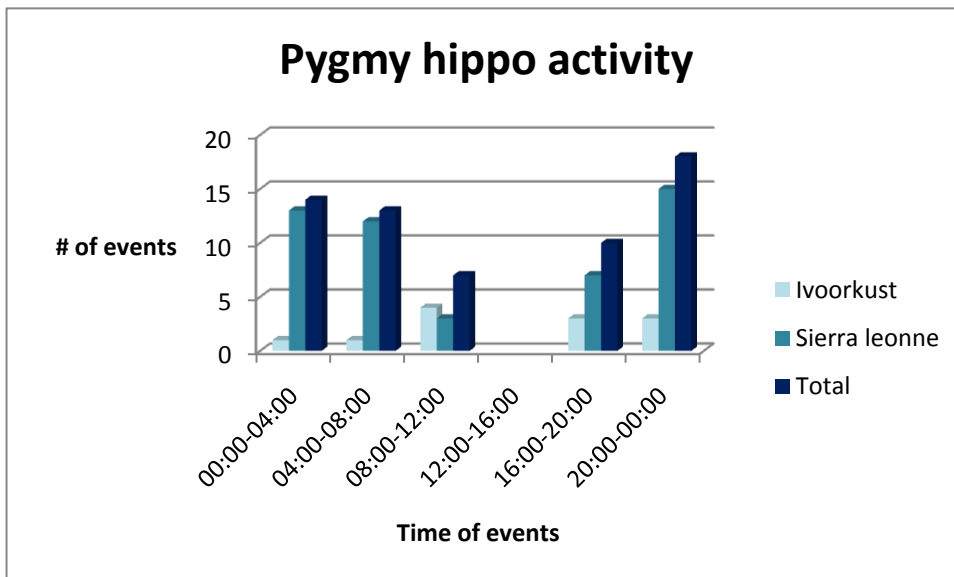


Figure 4b. Combined data on the activity pattern of pygmy hippos of this study and the study of Conway (2008)

To be able to estimate the population density of pygmy hippos either a capture-recapture method should be used or a method where the camera locations have been predetermined (random or in a grid) and cameras are placed exactly at that spot, regardless the situation at that location. In this study cameras were placed next to an animal trail, because the capture rate of pygmy hippos is very low. As a result I can only compare relative densities between sampled areas, because I was not able to distinguish individuals and the number of camera captures was not sufficient. Still, on several pictures clear scars could be observed on the body (*figure 8*). To estimate pygmy hippo population densities in the future with camera traps two cameras should be placed on either side of the road to observe both sides of an individual (Karanth and Nigels 1998) and a longer period of sampling should be obtained to increase the amount of trap events. Another wide used method to estimate animal population densities is by collecting all tracks of a species along several transects, which can be extrapolated for a larger area.



Figure 8. Recapture of an individual based on the scars visible on the body.

Footprint analysis

During the pilot study 5 individual pygmy hippos were measured (table 2); two adult males, two adult females and one juvenile female. No clear difference in toe measurements was found between male and female. The juvenile was measured at an age of 4 and 12 months, showing a clear difference with the adult toe sizes even after one year of age. These measurements are used as a reference for the measurements obtained in the field.

Age class	Toe size (cm)
adult (>2 year)	5.0-5.5
Juvenile (4 months)	3.5
Juvenile (12 months)	4.0

Table 2. Toe measurements of pygmy hippos living in captivity

During the fieldtrips all clear footprints were measured. Only the width of the front toes was measured to minimize potential measuring errors. During the research period 24 footprint measurements were taken (figure 5). Since the forest floor is very moist and slippery, often the footprints were not clear and out of shape. For the ones that were clear and measured it's important to obtain a standard deviation, to determine the measurement error. On three occasions I was able to measure a number of footprints of the same trail. After standardizing the measurements of the trails a standard deviation of 0.095 mm was found, which means the actual size of a measured toe can differ +/- 1mm ($n=24$, $p<0,05$).

The graph in figure 5 appears to show two groups of footprint sizes, namely 4.4-4.8 cm and 5.0-5.5 cm. A test confirms that the data is not normally distributed (*Shapiro-Wilk*, $n=24$, $p=0.020$). The footprint measurements in the zoo showed no significant difference between males and females, which suggest that the smaller toe sizes measured in the field are of juveniles. Interestingly, if pygmy hippos would give birth all year round I would expect a unimodal distribution, since all ages, and therefore toe sizes, are present at that time. However, the data shows a gab between 4.8 and

5.0 cm and the first measurement starts only at 4.4 cm. Part of the ‘missing’ data below 4.4 cm can be explained by the fact that during the first 3-5 months a young pygmy hippo hides in the vegetation and does not walk around leaving footprints (Roth *et al.* 2010; Hentschel 1980), but zoo measurements revealed that at the age of 4 months a juvenile has a front toe size of 3.5 cm, which again leaves a gab of proximately 9 mm between 3.5 and 4.4 cm.

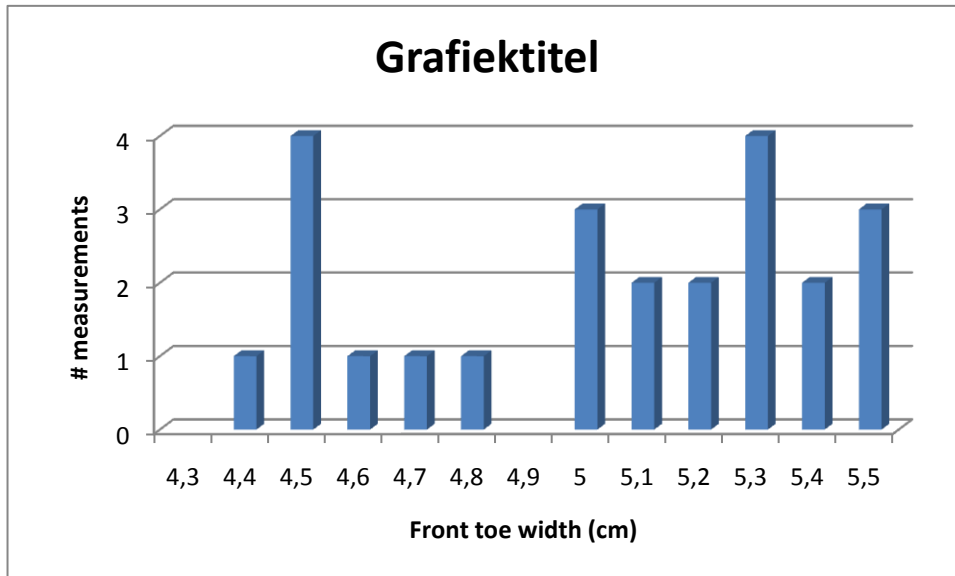


Figure 5. Footprint measurements, showing the width of the front toe

The gabs between 3.5 and 4.4 cm and 4.8 and 5.0 cm might be explained by the possibility that pygmy hippo's do not give birth all year round, but that they have a birth season. In that case there will be a group-shift of juvenile footprint size from the moment a juvenile pygmy hippo start walking along (toe size proximately 3.5 cm) until they reach their mature footprint size and a gab during the year will be observed between juvenile and adult footprint size. Contrarily, if pygmy hippos give birth all year round all footprint sizes would be observed at any time a year. The theory that pygmy hippo's have a birth season is supported by two facts; the first is that female pygmy hippos give birth on land (Robinson 2009), since newborn pygmy hippos can't swim during the first period of their life (Roth *et al.* 2010). Therefore, it would not be favorable to give birth during the rainy season, since large parts of the forest floor are flooded and the chance of drowning increases, so it would be more favorable to give birth just after the rain season. Secondly, the rain forests of west-Africa do show seasonality in both precipitation and temperature and therefore show variability in seed production during the year (Anderson *et al.* 2005). In fact, the highest seed production is during the months after the rain season, what would favor birth to take place just after the rain season (*figure 6*).

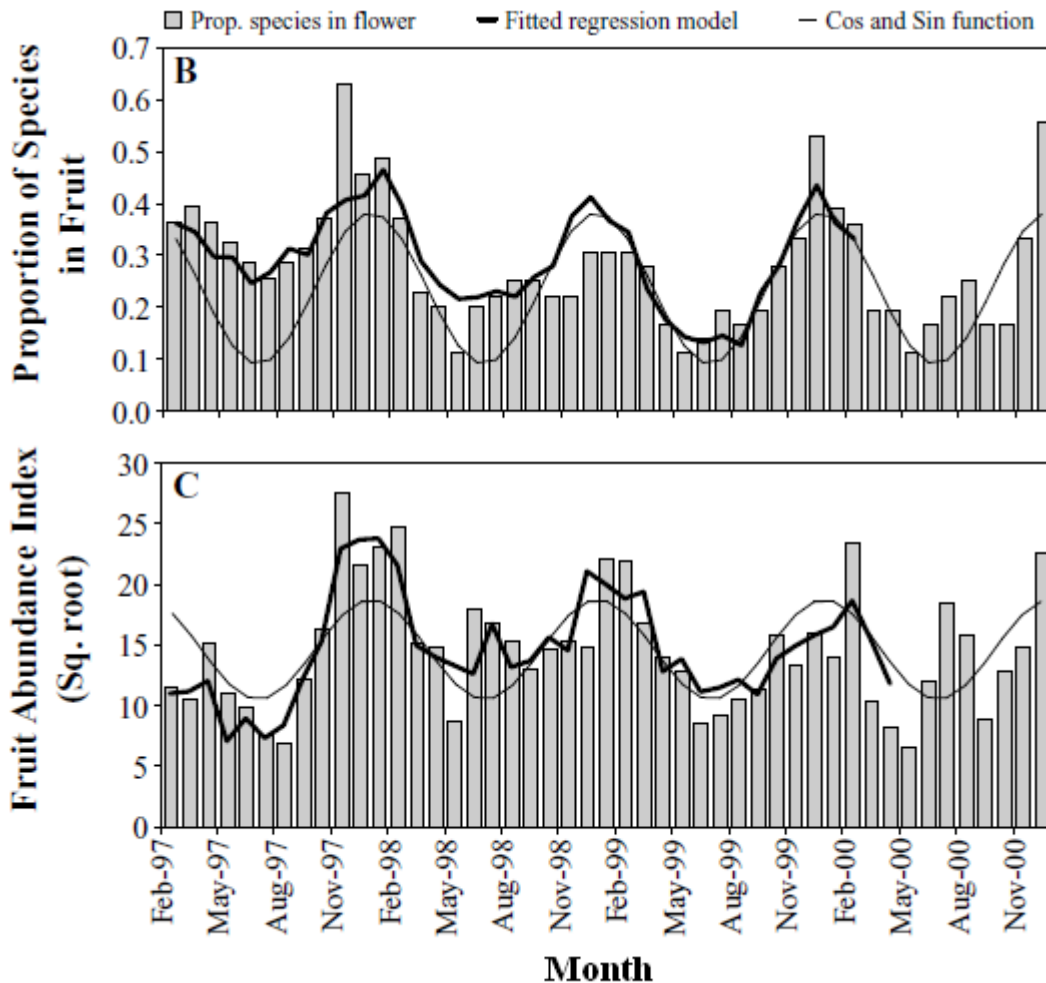


Figure 6. The proportion of all measured tree species in fruit and the fruit abundance index measured at four different periods per year for four years in the Tai National Park, Côte d'Ivoire (Anderson et al. 2005)

Still, the juvenile footprint measurements taken in captivity do not correspond with the juvenile footprint sizes observed in the wild. The front toe size of an adult pygmy hippo varied between 5.0 and 5.3 cm ($n=4$), what corresponds to the toe sizes observed in the wild. However, the toe size of a juvenile pygmy hippo in captivity of 12 months was 4.0 cm (table 2), while toe sizes in the wild varied between 4.4 and 4.8 cm. There can be two explanations for this difference; the first is that there the measurement taken in captivity is not represent able, since its only 1 measurement and this individual might be relatively small or growth in captivity doesn't equal growth in the wild. Still, the growth of this individual did not differ from other individuals born in captivity and the difference between 4.0 and 4.4 cm is relatively large to be explained by growth arrears, especially because if the theory on the birth season is right the juveniles in the wild were only 9 months old. The second explanation is that the observed footprint sizes are in fact of 1.5-2 year old juveniles. According to the zoo experts a juvenile pygmy hippo will only reach mature size after 2 years. Moreover, almost all small footprint measurements existed of a single animal trail, which suggests it concerns an independent juvenile (without parents). Still, that would imply that during their first year juvenile pygmy hippos do not show much activity, since we did not find any footprint sizes below 4.4

cm. That can be explained by the fact that after 1 year a juvenile is still almost half the size of an adult and therefore vulnerable to predation.

Finally, out of the 24 measured footprints 8 belonged to the group of small prints. If this group consists indeed of juveniles the status of the population can be determined; 33% of the population consists of juveniles, which compared to similar mammal species would indicate an increasing population (Conway and Goodman 1989; Rothley 2004; Owen-Smith 1988; Robinson and Redford 1991). Since 24 measurements is not much I calculated the range of the percentage juveniles with the *Wilson Score 95% confidence interval*, which indicated a range of 17.7-53.5% ($n=24$). That means that with this amount of measurements the status of the population is between 'increasing' and 'increasing fast'. Still, if the footprint measurements are of 2 year-old-juveniles, the percentage of 1 year-old-juveniles is higher and would indicate a more stable to growing population. To reach a deviation of 5% from equality a sample size of $n=340$ is necessary. A final comment is that, since individual footprints can hardly be compared and footprints have been taken in the same area in different periods, some individuals can be counted double. Therefore, the data can only be used as an indication of the local situation.

Seed experiment

The result on seed dispersal by pygmy hippo's different than expected. During my field work I collected feces of pygmy hippos on different locations and over the period of February-June. I collected 18 samples of which only one sample contained 2 vital seeds, of the species *Sacoglottis gabonensis* (figure 7b). All the other samples did not contain any vital seeds ($\text{size} > 5\text{mm}$). As a comparison I counted the amount of vital seeds in elephant (*Loxodonta africana*) droppings. 5 samples contained 40-60 vital seeds each, of the species *Sacoglottis gabonensis* and *Parinari excelsa* (figure 7c). All elephant droppings observed contained a large amount of seeds, of which many seeds had already germinated. Therefore, compared to elephants, the contribution of the pygmy hippo in the dispersal of seeds ($> 5\text{mm}$) is negligible.

This conclusion was even more supported when I further investigated the feces samples. All the samples contained small peaces of wooden material (2mm-10mm), up to half of the total biomass. Two independent botanists (Centre Suisse, Côte d'Ivoire and Wageningen University, The Netherlands) confirmed that the wooden structures are parts of a seed case. Therefore, Pygmy hippos do eat fruits as was stated in literature (Roth *et al.* 2004; Hentschell 1990), but they consume the fruit as a whole, including the seed. The seed case is destroyed and the seed itself is digested. Hentschell (1990) observed a pygmy hippo in captivity consuming a type of fruit (*Anthonotha fragrans*) by using its lips to crush the fruit case on the ground to consume the actual seed itself. The fruit of *Anthonotha fragrans* (figure 7a) consists of a hard wooden shell in which the seeds are embedded, while the fruit of the *Sacoglottis gabonensis* consists of a seed embedded in a nutshell which is covered with flesh. Apparently, it depends on the type of fruit whether the fruit is consumed as a whole or only the seed is consumed, but it is clear to say that the seed itself takes an important place in the diet of pygmy hippos in the wild.



(a) *Anthonotha fragrans* (+/- 20cm) (b) *Sacogluttis gabonensis* (+/- 5cm) (c) *Parinari excelsa* (+/- 7cm)

Figure 7. Three types of fruit that are known to be part of the diet of the pygmy hippo (Hentschel 1990).

Discussion

When measuring footprints the width of only one toe was measured, often due to practical reasons; many prints weren't clear enough to measure both toes. As a consequence both the left and the right toe have been used separately as a measure for the footprint of an individual. According to the footprints taken during the pilot study there is a slight difference between the toes (1-3mm). Since this difference in size has not been taken into account during the field measurements the uncertainty in the size versus age comparison increases. Still, the size difference between the toes is not large enough to change the theory on the birth season and juvenile activity; the standard deviation (0.095 mm) was derived from a sequence of toe measurements, in which the left and right toe were measured randomly, while the difference between the two groups in toe size (figure 5) is 4 mm. In future research both toes should be measured and averaged, to obtain better measurements.

The theory of a birth season and of the age and size distribution is based on only a small number of measurements (captive individuals=5, wild individuals=24). Therefore, although the theory seems applicable and confirmed by the data available, more research should be done to confirm their reproductive activity and population structure. Also, all measurements were taken within or close to the area shown in *figure 3*. Regarding to the suggestion that the population is likely to be stable or even slightly increasing, this can only be stated for the sampling area in Taï. Conditions due to poaching vary throughout the national park, so population status might vary per region.

To compare different camera trap sample areas the conditions need to resemble as much as possible. In this case the sample areas were not sampled simultaneously, but one at the time. Therefore, the climatic condition differed a lot; for instant, during the last two sample periods the rainy season had started, so conditions changed dramatically. In future research it would be best to sample different areas all at the same time. If the amount of cameras is limited different areas can be measured in different years at the same time of the year. Still, conditions can differ from year to year, so they need to be compensated.

During the sample period some cameras broke down or an object (like a fallen branch) blocked the trail. This means that the camera did not take the amount of trap nights necessary. A trail being blocked by a branch can't be controlled; you might notice it when it happened next to the camera, but it can happen out of sight as well. Therefore, I believe that this is a natural event that shouldn't have to be taken into account. When a camera breaks down, you will lose potential data and thereby trap nights. To still be able to compare different locations, the number of individuals should be divided by the number of trap nights, giving the number of individuals per trap night.

In practice it can be rather difficult to find a proper animal trail, so some camera's are placed beside large trails where many animals pass, while another camera is placed at a small trail where only a few animals pass. Generally, this should not matter because when you search for the best trail you can find it will represent the area as good as possible. However, it is very important that a camera is placed always alongside an animal trail, not only to make a proper comparison, but also because it turned out that no matter how promising a spot might look they will capture far less animals than even a small animal trail.

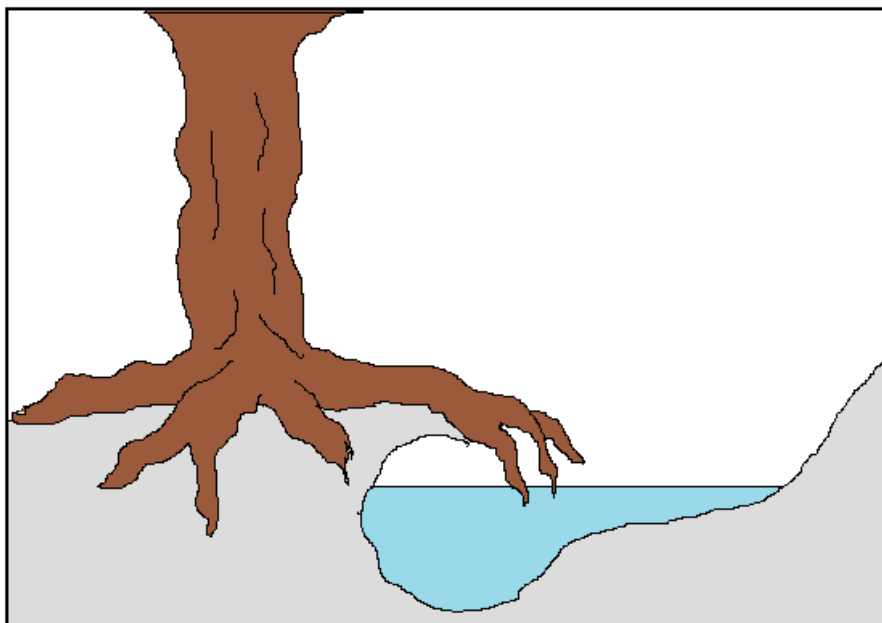
During the feces analysis we only looked at seeds that were larger than 5 mm, because they are easily located within the dung and the fruits described in literature were much larger (>30 mm).

Therefore, no conclusion is drawn on the potential effect of pygmy hippos on the dispersal of seeds <5 mm.

During the first month (February-March) of fieldwork twice I observed pygmy hippo's coming out of a hole in the riverbank, situated underneath the dense root-system of a large tree (*figure 8*). The river at that time (the dry season) was barely 15-20 cm deep, but the space underneath the roots was much deeper. The hippos didn't come out at once, so they most likely felt safe hiding. In one case 2 hippos were hiding in the same den, of which one looked smaller and was likely to be a juvenile. Also, the literature mentioned stories of and/or fresh tracks around or going into these dens (Hentschell 1990, Roth *et al.* 2004, Appendix 4). Therefore, the following suggestions might explain this behavior:

- Pygmy hippo's use the dens to protect their skin during the dry season, since the water is deep enough for the hippo to wet the whole body.
- They use it for protection and/or to rest without disturbance during the rainy season, since the den provides shelter and a hiding place. Adult hippos have few enemies, but are extremely cautious and can be disturbed.
- The den's are used mainly for and by juvenile pygmy hippo's, for protection.

Further research should be done, because the dens are created by rivers carving out the space underneath large root systems of old trees, which is likely only to occur in primary rainforest, since it takes a long time for the river to create this space and a long time for a tree to have such a large root system. It is not clear whether pygmy hippos contribute actively in increasing this space, but it is possible since in one location the depth of this space was measured to be at least 4-5 times as deep



(50-60cm) as the river itself. It is unlikely that the river itself creates this pattern. If pygmy hippos turn out to be (partly) dependent on these dens, then indirectly they are (partly) dependent on primary rainforest. This in contrast with Roth *et al.* (2004) who suggested that pygmy hippos can survive living in secondary rainforest habitat.

Figure 9. Schematic image of a den used by pygmy hippos

Acknowledgements

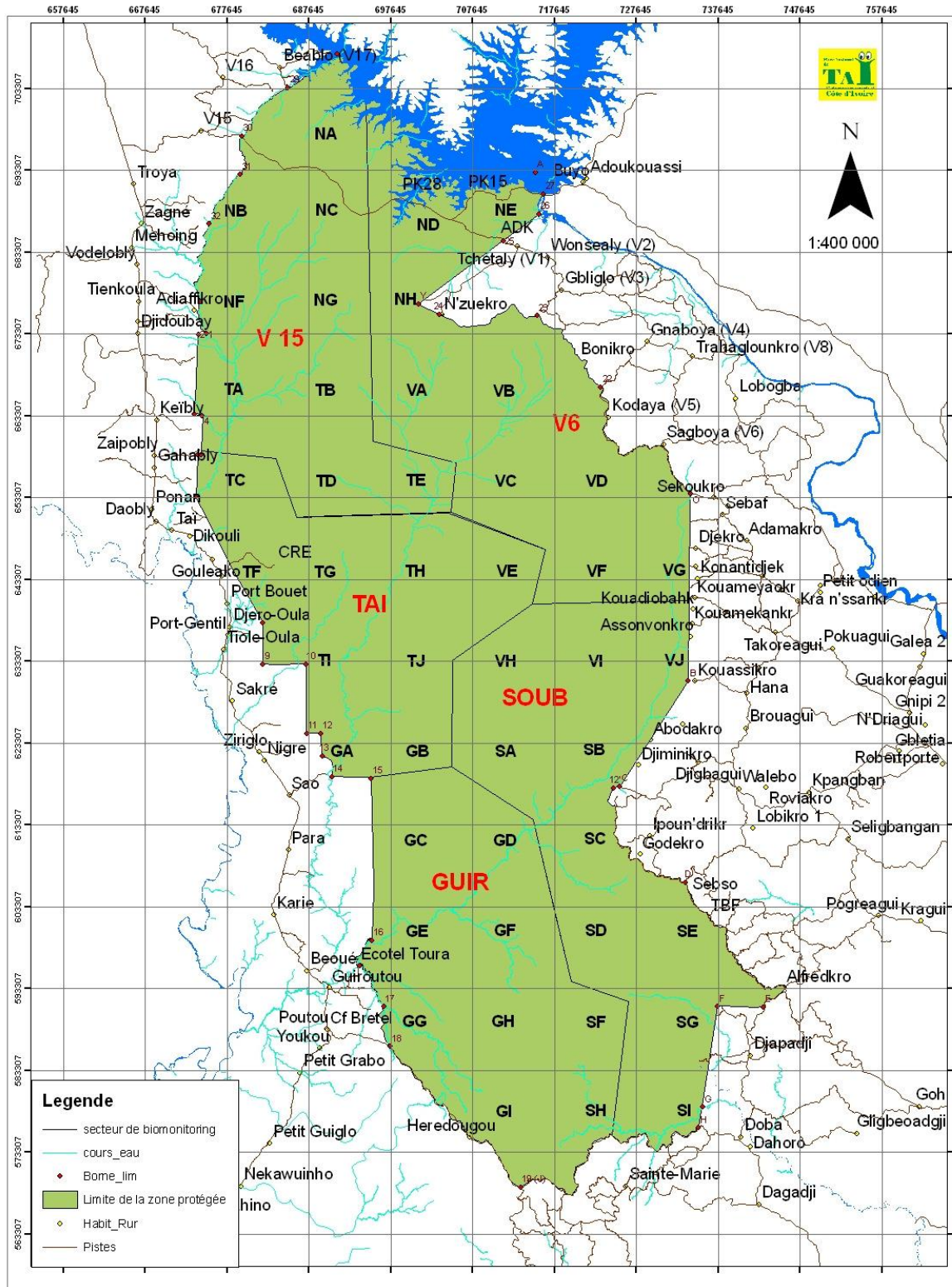
I want to thank my supervisors, dr. Monique Paris (*IBREAM, Institute For Breeding Rare and Endangered African Mammals*) for her constant help and support during the preparation and performance of the research project, dr. Pim van Hooft (*Wageningen University, Resource Ecology Group*) for all his feedback on the methods and the statistical analysis and dr. Karim Ouattara (*Centre Suisse de Recherche Scientifique en Côte d'Ivoire*) for his participation, facilitation and constant support during the performance of the project. I want to thank my colleague ir. Henk Eshuis for his cooperation during field performance, dr. Inza Koné (*Centre Suisse de Recherche Scientifique en Côte d'Ivoire*) for his help and support and my field assistants Donation and Sio for all their help and expertise in the field. This research was supported by funding of the Royal Zoological Society of Scotland. I also want to thank the Rotterdam Zoo Blijdorp and Burger's Zoo Arnhem for their support in the pilot study to obtain footprints of pygmy hippos in captivity.

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Appendix 1. Map of Taï National Park



Appendix 2. 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: Do Not 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

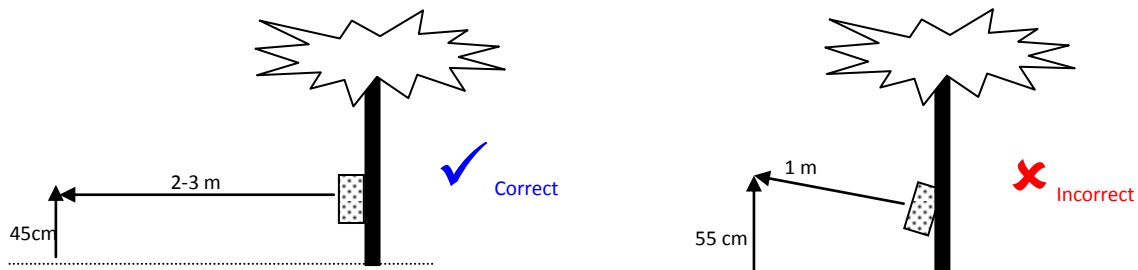
- Switch on camera
- Press **MENU** to activate screen if it does not appear
- Press **MENU** again to begin programming the camera settings - the setting to be changed will be flashing
- *Resolution* will be the first setting and will be flashing
- Press **OK**
- Use up/down keys to change *Resolution* 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. 1st 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° 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 3. 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.

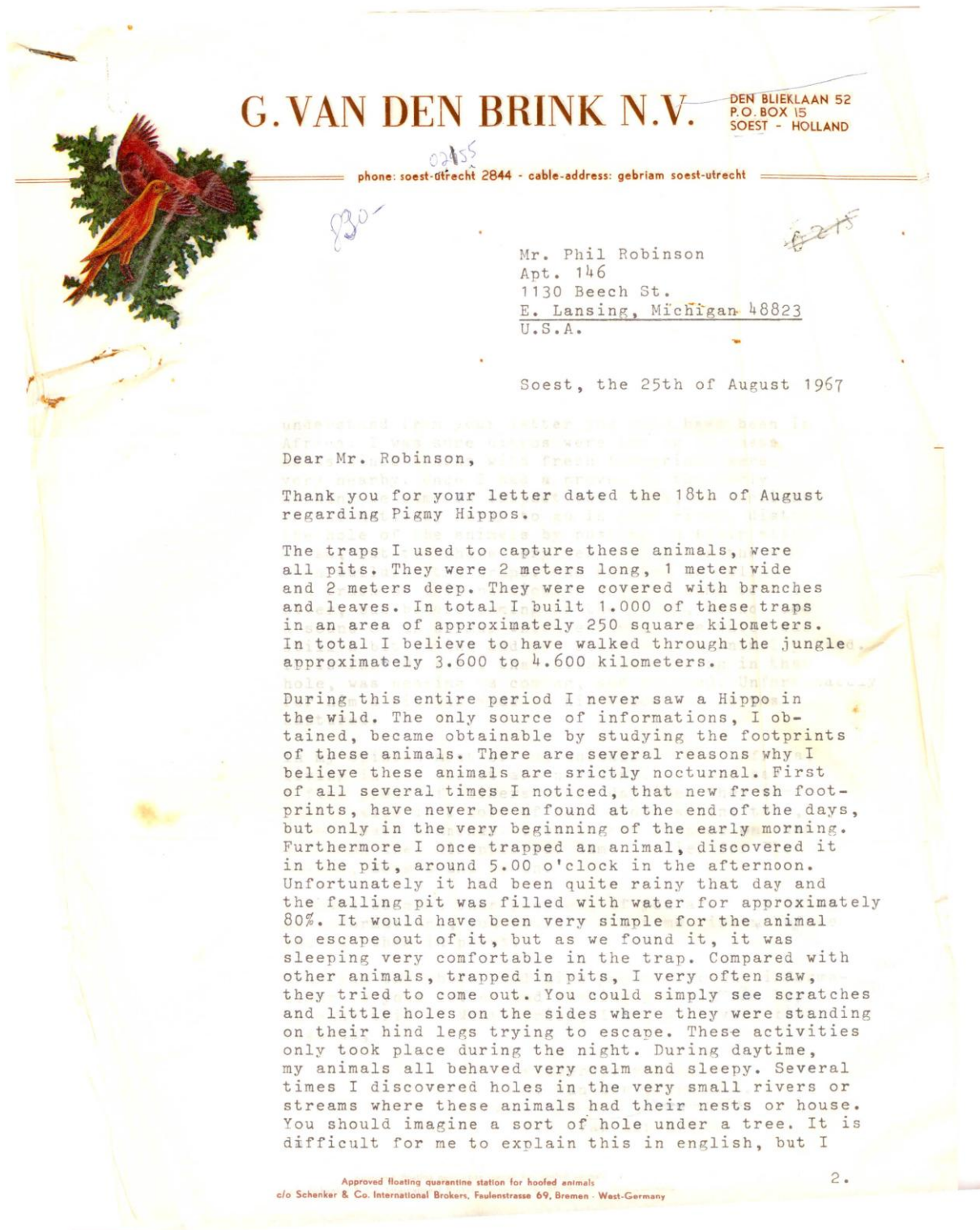
File structure for download of photos

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 <i>e.g. S1-1A-01</i>
Picture code	The automated code assigned to the picture by the camera <i>e.g. DSC_0001.jpg</i>
Date of photo	Should be entered in the following manner: <i>month-day-year</i>
Time of photo	Be sure to use the <i>24 hr clock</i>
Genus	First part of the scientific binomial of the Genus to which the species belongs <i>e.g. Homo</i>
Species	Specific name <i>e.g. sapiens</i>
Common name	<i>e.g. Human</i>
Person Identifying species	<i>e.g. Ben Collen</i>
Trap event number	These should be numbered sequentially (<i>1, 2, 3...n</i>). 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!!**

Appendix 4. Specialist information wat een gave brief die je hier hebt, wat leuk!!!!





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2.

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understand from your letter you once have been in Africa. I was sure Hippos were laying in these nests since tracks with fresh footprints were very nearby. Once I had a prove. In the early morning we came to inspect the traps, we mentioned to the natives, never to go in that river, disturb the hole of the animals by pushing in their sticks or so, but to behave very very calmly in the area when building the traps. One morning we followed the track of this particular animal, came to the river, but before coming to the river, we noticed a sound of an animal which escaped. The water was still a bit waving and you could see an animal passed. It is for 99% sure, that Hippo was laying in that hole, was hearing us coming, and escaped. Unfortunately for him a pit was made on his track and he was captured.

In my opinion most of the animals in West-Africa, living in the forest are nocturnal. I once saw a fine group of Duikers under daytime. They were laying also in a sort of nest under a fine tree, under heavy branches. I so to say stepped on them and then they disappeared. Same applies for Elephants, Bongos and so on.

I would be more then pleased, if you are once using my informations, you would contact me firstly before you put them in print.

Trusting the above will give you sufficient informations to your letter and wishing you all the best on your trip to West-Africa, I am, with very best regards,

sincerely yours,
G. van den Brink N.V.

F.M. van den Brink.

Approved floating quarantine station for hoofed animals

c/o Schenker & Co. International Brokers, Faulenstrasse 69, Bremen - West-Germany