Studying the distribution and abundance of the Endangered pygmy hippopotamus (*Choeropsis liberiensis*) in and around the Gola Rainforest National Park in southeastern Sierra Leone

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Abstract

The pygmy hippopotamus *Choeropsis liberiensis* is an endangered and elusive species whose global distribution is restricted to only four countries in the Upper Guinean Forests of West Africa. Exact numbers of individuals surviving in the wild are unknown as well as many other aspects of their ecology and behavior. Within Sierra Leone, the Gola Rainforest National Park (GRNP) and its surroundings as well as the adjacent Tiwai Island seem to host the biggest remaining population. Previous work in the GRNP area suggested that pygmy hippos are mainly distributed along larger streams in the community areas outside GRNP, though no surveys particularly targeted pygmy hippos inside GRNP. Second, past pygmy hippo surveys in GRNP did not follow any standardized survey designs and thus are not repeatable nor is it possible to calculate any pygmy hippo abundance or density. Finally, so far there was no possibility to distinguish different individuals of pygmy hippos which would help to get an idea about the population size of pygmy hippos in and around GRNP. The present study therefore focused on pygmy hippo surveys along streams inside GRNP, on the development and testing of new survey designs and on camera trapping in order to identify different individuals on the camera trap pictures. Twenty three streams were surveyed during 44 survey days between May and December 2013. In total, 56 signs, mainly footprints and dung, were observed and mapped. Comparison with previous results suggests that pygmy hippos are really more abundant in the community area and therefore are not adequately protected by GRNP without involvement of local communities and conservation activities focusing on the community area. Knowledge about pygmy hippo locations should be included into land use planning exercises when farming activities are planned with communities. Two survey designs focusing on 2-ha plots evenly distributed along streams were developed and tested, but further tests are necessary in order to finally decide on their effectiveness and suitability. Due to the high level of anthropogenic disturbance in the deployment area, no pygmy hippos were recorded on camera traps. Future research activities should continue to survey more streams inside GRNP, to test the developed survey designs and to deploy camera traps in order to allow for distinguishing different pygmy hippo individuals.

Dedication

It is my honor to dedicate this thesis to my late parents, Nahmanei and Nyepudolo Garteh. Though they are dead, their motivations and advice led me to this point in the journey of education. I am also pleased to dedicate this thesis to my wife Fatu Garteh for standing by me from the formative to the summative of my studies.

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CERTIFICATION

I, Dr. Annika Hillers, certify that Mr. Jerry C. Garteh in the Department of Biological Sciences, School of Environmental Sciences, Njala University, carried out this research work entitled **"**Studying the distribution and abundance of the Endangered pygmy hippopotamus (*Choeropsis liberiensis*) in and around the Gola Rainforest National Park in southeastern Sierra Leone".

Signed……. **Date……**

Supervisor

CHAPTER ONE

1.0 Introduction

The pygmy hippopotamus or pygmy hippo (*Choeropsis liberiensis*) is a species of high conservation concern appearing as endangered on the IUCN Red List (Lewison & Oliver 2008). Its range is limited to only four countries in the world, located in the Upper Guinea Forests zone: Sierra Leone, Liberia, Côte d'Ivoire and Guinea. Within this range, the loss of habitat due to deforestation led to a much restricted and fragmented distribution of pygmy hippos (Mallon et al. 2011, Conway 2013).

Previous research results indicate that within Sierra Leone, the Gola Rainforest National Park (GRNP) and its surroundings harbor the most important population of pygmy hippos (Hillers & Muana 2011). Pygmy hippos are restricted to forested areas close to rivers and streams (Eltringham 1999, Conway 2013), and due to their elusive life style there is a lack of knowledge about many aspects especially concerning their ecology, habitat requirements and behavior (Mallon et al. 2011, Hillers & Muana 2011, Conway 2013). Major threats to pygmy hippos are the loss of habitat and hunting for bushmeat (Lewison & Oliver 2008, Hillers & Muana 2011, Conway 2013).

Results of previous pygmy hippo research in the Gola Forest area indicate that the major part of the present pygmy hippo population occurs in the community forest area outside the protected area (Hillers & Muana 2011). However, so far surveys focused more on the areas around big streams outside of GRNP and no intense surveys were made along the smaller streams inside the National Park. Thus, without the knowledge about the situation of pygmy hippos inside GRNP, it might be premature to conclude that pygmy hippos are more abundant outside than inside GRNP. However, in case it is true that pygmy hippos show a preference for the community forest area around GRNP, it shows that i) the pygmy hippo is not effectively protected by the established National Park and ii) there is an urgent need to develop a conservation strategy involving communities and their livelihood needs.

There are no reliable estimates for population sizes of pygmy hippos. Most recent estimates range from 2,000 to 3,000 individuals in the overall range and from 100 to 150 individuals for the Gola Forest and Tiwai area (Mallon et al. 2011), though this estimate might be too high. The lack of knowledge of important factors such as population size, home ranges, exact distribution, feeding patterns, and other ecological features as well as detailed threats make it difficult to develop a detailed conservation strategy for pygmy hippos. This is also true for the area of the GRNP, though recent projects significantly contributed to the knowledge about this elusive species (Hillers & Muana 2011, Conway 2013).

So far, no standardized survey techniques were used for the pygmy hippo surveys in and around GRNP and surveys mainly relied on reconnaissance techniques. Therefore, it has not been possible to directly compare data from different areas at GRNP, or to repeat surveys in the same area and compare data from different times. The latter would allow for the detection of potential changes in the distribution and abundance of pygmy hippos. This knowledge would be very important for an effective management and protection of pygmy hippos and their habitats.

Additionally, there was no possibility to distinguish different individuals of pygmy hippos which would help to get an idea about how many individuals occur in a particular area. Such knowledge would be necessary in order to make reliable estimates of population sizes.

Considering previous research results, this thesis should create the foundation for i) a detailed understanding of the distribution and abundance of pygmy hippos in and around the GRNP, which will be used for the recommendations to the GRNP management and the development of a species conservation action plan for the GRNP area, ii) a standardized survey design that should serve as a guide for future pygmy hippo surveys in GRNP and also other areas, and iii) a camera trapping survey which potentially will allow for the distinction of different individuals of pygmy hippos in a defined area based on photographic records.

1.1 Statement of the Problem

The pygmy hippo (*Choeropsis liberiensis*) is an endangered and elusive species that lives in only four countries in the world within less than 5,000 km^2 (Lewison & Oliver 2008, Mallon et al. 2011). The Gola Rainforest National Park (GRNP) in south-eastern Sierra Leone is considered as one of the last remaining strongholds for this species in the Upper Guinea Forests. The population status for this shy species in Sierra Leone, including the GRNP, is not known. Major threats to pygmy hippos are habitat destruction and fragmentation, as well as poaching. GRNP in Sierra Leone is a biodiversity hotspot, with a great diversity of flora and fauna (Klop et al. 2008, Hillers 2013). The local extinction of pygmy hippos might trigger a series of effects in the ecosystem, causing a break down in some key ecological processes, such as seed dispersal and predation, nutrient recycling etc. eventually jeopardizing the ecosystem biodiversity and integrity in the long term (Brooks et al. 1997). Therefore, a detailed knowledge of the distribution, ecology and threats is needed in order to effectively protect the pygmy hippo in and around the GRNP.

1.2 Aims and Objectives

The research conducted in this thesis project focused on three aims. First, the status and distribution of pygmy hippos inside GRNP should be assessed by conducting surveys along streams. A detailed knowledge about the distribution of pygmy hippos in and around GRNP is needed for adequate protection of this species and can help the GRNP management with choosing the right conservation measure. Second, a new survey design for surveys along streams should be developed and tested. This design then should be the basis for standardized surveys in the future. Third, a camera trap survey also using a newly developed design should be conducted in order to distinguish different individuals of pygmy hippos which would help determining populations sizes and home ranges of pygmy hippos.

1.3 Significance of the study

The last pygmy hippo survey on a national level in Sierra Leone was conducted alongside a nationwide primate and chimpanzee survey in 1979 and 1980 (GoSL 2010). Another recent nationwide survey only focused on chimpanzees (Brncic et al. 2010). For other wildlife species, such as the pygmy hippo, the information on the distributions and densities is very patchy, unknown or unreliable. In general, compared to the times of the old nationwide surveys, it is believed that especially habitat destruction and hunting have resulted in the massive reduction in the biotic communities within Sierra Leone (GoSL 2010). Only 5% of the country's original forest cover remains (NBSAP 2002).

In recent years, pygmy hippo surveys were conducted around the Loma Mountains by the Zoological Society of London and Njala University (C. Ransom & I. Bakarr pers. comm.), Tiwai Island (Conway 2013) and the area of the GRNP (Klop et al. 2008, Hillers & Muana 2011, Hillers 2013). However, due to the elusive nature of pygmy hippos, though recent research activities were much more intense than throughout the last decades, knowledge about many details concerning the ecology and distribution of pygmy hippos is still lacking. Research activities confirmed that pygmy hippos are rare and only restricted to a few specific localities. However, none of the research activities, also in other range countries, resulted in reliable figures for population sizes (Mallon et al. 2011).

This thesis is of significance on a local, regional, national and global level. The pygmy hippo only remains in the wild in four countries of the world: Sierra Leone, Liberia, Guinea and Côte d'Ivoire. Although being a large mammal species, pygmy hippos are very secretive and elusive and only little is known about their ecology, behavior and distribution. The information about their population sizes is very rough and no standardized surveys formed the basis for the estimation of their numbers (Mallon et al. 2011). At the same time, the habitats of pygmy hippos are threatened by continuous forest destruction. Remaining populations are highly fragmented and

in most areas, pygmy hippos are also targeted by hunting for bushmeat (Mallon et al. 2011, Greengrass 2011, Hillers & Muana 2011, Conway 2013).

The area of the GRNP is one of the last remaining suitable habitats for pygmy hippos and has been shown to harbor one of the last strongholds in Sierra Leone and also in the Upper Guinean Forests. The protection of pygmy hippos, being a species of high conservation concern for GRNP, thus is of very high importance from the local to the global level. Any additional information collected on this elusive species is contributing to a better knowledge which will allow for its better protection.

The contents of this thesis, focusing on the distribution of pygmy hippos inside GRNP (compared to the corridor areas) and the development of new survey designs are building an important foundation for the protection of pygmy hippos by providing crucial information to the GRNP management. Second, it aims to develop standardized survey designs which can be repeated throughout future surveys and in other regions, thus making results from pygmy hippo surveys in different times and areas more comparable. In GRNP, the developed method is supposed to be used in the Biodiversity Monitoring under a 30-year Carbon Project.

1.4 Limitation of the study

The major limitation of a taught master thesis is the limited time available for field research in addition to the many challenges on the way including completion of the required class-courses. Constrains of getting to your destination on time on dilapidated roads leading to the forest is of no exception to this research.
Additionally, access to the study area was denied by adjacent communities for the only area inside the Gola Rainforest National Park where numerous pygmy hippo signs were observed and where new survey designs for surveys along streams and camera trapping should have been tested. This led to delays and the necessity to select another accessible test area outside the Gola Rainforest National Park.

Chapter Two

2.0 Literature Review

The existing literature on pygmy hippos is covering different fields and dates back to almost 150 years ago (e.g. Price 1875). Early literature mainly deals with the capture of pygmy hippos and their transfer and survival in European and American zoos (Steck 2008). First ecological works and in-depth research on pygmy hippos were described by Robinson (1970). In the following, literature covering different fields will be reviewed, such as the history of pygmy hippos, its distribution and its threats. Other biological aspects will be described in Chapter 3.

2.1 Historical Records

The pygmy hippopotamus (*Choeropsis liberiensis*) is one of the two extant hippopotamus species whose first historical record dates back to 1873 when pygmy hippos were first taken away from Africa to other parts of the worlds. The first pygmy hippo taken to Europe was captured by a hunter in Sierra Leone. This young pygmy hippo only survived for a few days after its arrival in Ireland (Robinson 1971). After the reported capture of this pygmy hippo forty years passed before Carl Hagenbeck engaged Hans Schomburgk to capture pygmy hippos in Liberia. Schomburgk captured five pygmy hippos and brought them to Hamburg in 1912 (Greed 1983). Three of these five animals were then sent to New York, where they were kept for almost 40 years and gave birth to many offspring. In 1913, the capturing of pygmy hippos to be carried to Europe continued with three additional animals from Liberia. The success story of ex-situ conservation of this elusive species was shown in 1919, when the first live birth of a pygmy hippo was recorded in New York Bronx Zoo. In the 1920s and 1930s, 28 additional animals were imported from different localities, and 37 animals were born in the zoos of Basel (4), Berlin (6), Leipzig (5), London (5), Munich (2), New York (7), Philadelphia (4) and Washington (5). Pygmy hippos became attractive to many great world leaders which is shown by the donation of a pygmy hippo to the President of the United States, Calvin Coolidge, by Henry Firestone in 1927, and by the naming of a pygmy hippo after Goebbels, the

infamous Nazi propaganda minister, in a German zoo in the 1930s (International Studbook 2011). At the end of the Second World War, pygmy hippos were again affected by the war when seven individuals, then representing one sixth of the captive population, died as a result of military action in the zoos of Berlin, Munich and Wroclaw.

After the Second World War, most zoos recovered and started importing pygmy hippos again. The number of importation of the species increased to 107 individuals between 1954 and 1975. The importation of pygmy hippos started decreasing after 1975, until it came to an end in 1982. Altogether, the International Studbook lists 158 importations between 1912 and 1982 (International Studbook 2011). The number of zoo births remained moderate in the 1950s and 1960s, but increased considerably in the 1970s, shown as the most successful period in the increment of the number of pygmy hippos in zoos. The most successful breeders were Basel (73), Washington (58) and Pretoria (41). As a consequence of the importations and breeding success, the total zoo population increased sharply after 1961 and the Studbook data suggested a maximum of 350 animals in 2001, followed by a decrease to just over 300 animals now (International Studbook 2011). However, the decrease can be attributed to the exclusion (lost to follow up) of 42 animals from the studbook population in 2002 because no one had any information on their status for seven or more years.

2.2 Global and Regional Distribution

The pygmy hippo is endemic to West Africa. While the subspecies *Choeropsis liberiensis heslopi,* that occurred in Nigeria and was last recorded in 1945, is thought to be extinct, known populations of *Choeropsis liberiensis liberiensis* occur in the Upper Guinean Forests in four countries: Sierra Leone, Guinea, Côte d'Ivoire, and Liberia (Figure 1). The largest population is believed to exist in Liberia and Côte d'Ivoire (Mallon et al. 2011). Compared to the historic distribution, today's distribution of pygmy hippos is less extensive, mainly due to the heavy loss of forests and serious habitat fragmentation. Remaining pygmy hippo populations are now highly

fragmented and some populations disappeared from previous sites (Mallon et al. 2011).

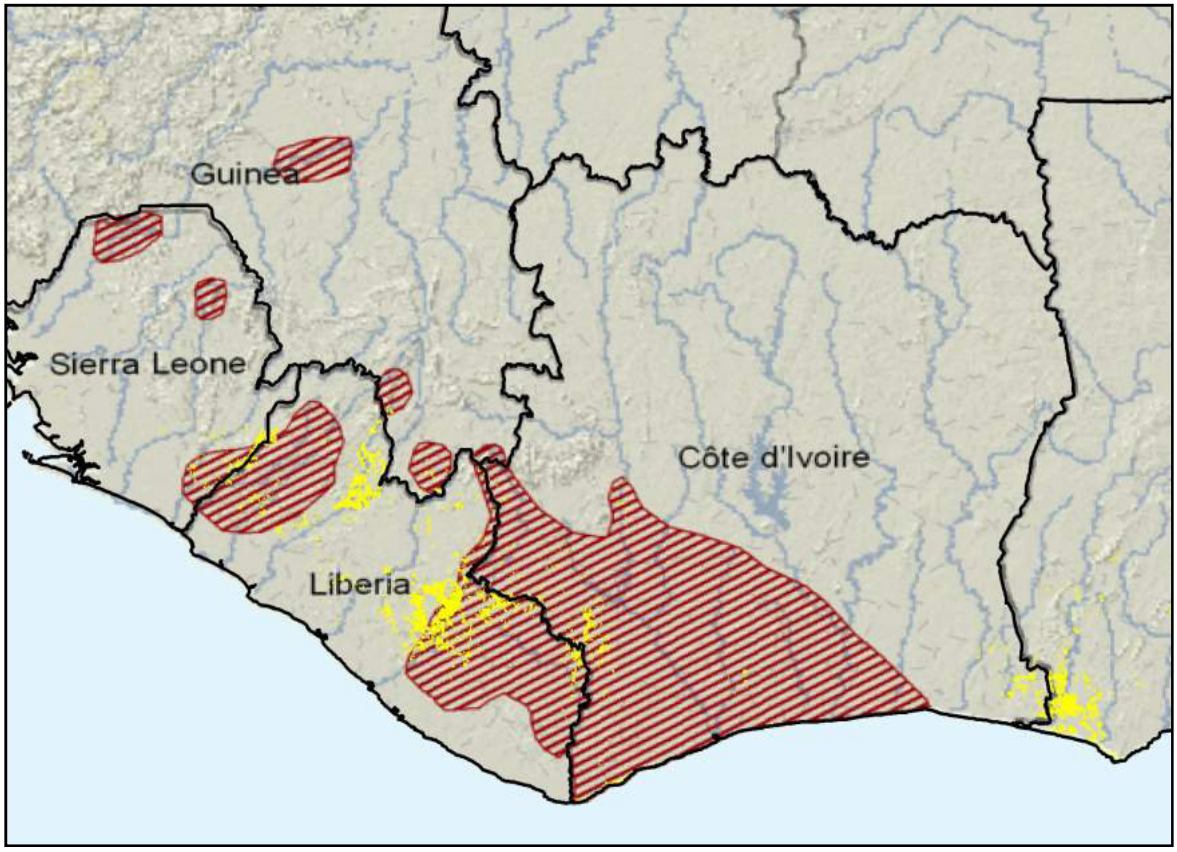

Figure 1: Global and regional distribution of pygmy hippos in the Upper Guinean Forests in West Africa (red areas) based on historical and recent records (map from IUCN 2012).

Detailed knowledge about the distribution of pygmy hippos in the four range countries exists depending on how intensely pygmy hippos were and are being studied in the respective countries and on the knowledge about habitat changes as pygmy hippos are unlikely to occur in highly transformed and destroyed habitats.

In Liberia, the stronghold of the remaining pygmy hippo population is believed to occur in the Sapo National Park in southeastern Liberia (Collen et al. 2011, Mallon et al. 2011). Further important sites are the forests between the Cestos and Senkwehn

Rivers (Robinson & Suter 1999), and the Gola and Wonegizi National Forests in northwestern Liberia (Mallon et al. 2011, Hillers 2013).

In Côte d'Ivoire, the Taï National Park in the South-West and other forests bordering Liberia harbor the most important pygmy hippo populations (Roth et al. 2004, Mallon et al. 2011).

Pygmy hippo work in Guinea was rather limited in the past, but the remaining population is believed to be restricted to the forest area in the South-East of the country, such as the Ziama, Diécké and Mont Béro forests (Mallon et al. 2011).

Within Sierra Leone, several recent research initiatives revealed the presence of pygmy hippos at several sites, sometimes giving quite detailed information about their distributions in respective areas. The area of the Gola Rainforest National Park in southeastern Sierra Leone and the adjacent Tiwai Island are likely to harbor the most important population of pygmy hippos within Sierra Leone (Hillers & Muana 2011, Mallon et al. 2011, Conway 2013, Hillers 2013). Other recent records were reported from Bumbuna, the Seli River close to Kafogo and the Loma Mountains (Mallon et al. 2011).

Historical records were made in Sierra Leone in 1979 and 1980 during a nationwide survey of hippos and Forest Elephants. This survey confirmed the presence of pygmy hippos north of the Loma Mountains Reserve boundary in a low land forest mosaic by the Bagbe and Bafin rivers (Teleki et al. 1980). Potential records from pygmy hippos from the Outamba Kilimi National Park in northern Sierra Leone however are not confirmed (Mallon et al. 2011) and might have been records of common hippos that occur in the Outamba Kilimi National Park.

2.3 Habitat

The preferred habitat of pygmy hippos are primary rainforests close to rivers and streams as well as *Raphia* palm swamps (Robinson 1970, Bülow 1988, Eltringham 1999). In the area of the Gola Rainforest National Park pygmy hippos were also

found in floodplains and swampy areas dominated by tall herbaceous vegetation and in patches of riverine forest (Klop et al. 2008, Hillers & Muana 2011). Roth et al. (2004) stress the importance of the presence of small streams with submerged trees, root hollows, and swampy depressions that can serve as hiding and resting places for pygmy hippos during the day.

2.4 Population Size

The current population size of pygmy hippos in the wild is unknown and estimations in the past varied a lot. The most commonly used estimate dates back to the early 1990s and estimated between 2,000 and 3,000 individuals in total remaining in the wild (Eltringham 1993). While other estimates reach higher numbers (e.g. 10,000 individuals only in Taï National Park between 1982 and 1986 and 5,000 individuals in Taï National Park in 1997 by Roth et al. (1997)), others see also the number of 2,000 to 3,000 as an overestimation (Lewison & Oliver 2008).

While the true population size is unknown, it is certain that the number of pygmy hippos in the wild decreased, especially given the serious loss of habitat in the Upper Guinean Forests and subsequent hunting pressure, also as forests became more accessible (Roth et al. 2004, Lewison & Oliver 2008, Mallon et al. 2011). Decreased numbers of pygmy hippos were also observed on the local level such as in the area of the Gola Rainforest National Park (Hillers & Muana 2011).

2.5 Threats and Threat Status

Major threats to pygmy hippos are habitat fragmentation and destruction as well as hunting for bushmeat and governmental weakness in law enforcement (Mallon et al. 2011, Conway 2013). In all range countries, there has been a significant loss of forests and only 5-10% of the original forest cover remain (Poorter et al. 2004). Growing human populations lead to an increased need for agricultural space and often destructive slash-and-burn methods are used. Other reasons for habitat loss

and fragmentation are commercial plantations, such as rubber, oil palm, cocoa and coffee plantations and commercial logging (Christie et al. 2007, Norris et al. 2010). The importance of bushmeat as a protein source for local people in West Africa and the preference for bushmeat even if other types of meat are available has been reported in different studies (Davies & Richards 1991, Greengrass 2011, Koroma 2012). The love for bushmeat also includes pygmy hippos and several cases of pygmy hippos hunted for bushmeat have been reported (Greengrass 2011, Hillers & Muana 2011, Koroma 2012). Greengrass (2011) reported the killing of four pygmy hippos by commercial hunters in Sapo National Park in Liberia within one month.

Lastly, though pygmy hippos are legally protected in all range countries under the 1968 African Convention on the Conservation of Nature and Natural Resources (Mallon et al. 2011), the species is suffering from inadequate protection as even in most protected areas where no hunting is allowed, such as National Parks, National Forests, Wildlife Sanctuaries and Classified forests, the level of law enforcement is often very weak or non-existent (Roth et al. 2004, Mallon et al. 2011, Hillers 2013). While the Gola Rainforest National Park is likely one of the best protected National Parks in West Africa, previous surveys suggest that the major part of the pygmy hippo population occurs outside of the National Park in the community forest area, where usually no law enforcement against bushmeat hunting for protected species exists (Hillers & Muana 2011).

Besides human threats to pygmy hippos, they also serve as prey for other large mammals, such as leopards and Nile crocodiles (Robinson 1970, Hentschel 1990, Roth et al. 2004). Smaller mammals like the African golden cat and the African civet, as well as Rock pythons might be able to kill young pygmy hippos (Eltringham 1999).

Based on its small and restricted range, the probably low number of individuals surviving in the wild and the numerous and serious threats to pygmy hippos, the species is listed as endangered on the IUCN (International Union for the

Conservation of Nature) Red List for Threatened species (Lewison & Oliver 2008). Furthermore, pygmy hippos are protected under the law of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora, CITES 2013) where they are listed in Appendix II (as *Hexaprotodon liberiensis*) which provides partial controls on international trade.

2.6 Conservation and Research Initiatives

Especially throughout the last years the interest and investment in protecting and studying pygmy hippos has increased, after a long break that likely was related to political unrest affecting the whole pygmy hippo range (Lindsell et al. 2011). Research and conservation projects were initiated in all four range countries and workshops and meetings were organized by the IUCN Species Survival Commission, partnered with the Zoological Society of London (ZSL) and Flora and Fauna International (FFI; Mallon et al. 2011). These workshops aimed at getting better knowledge about the status of pygmy hippos in their natural range, their current population size, threats they are facing and about current research and conservation initiatives. Outputs of these workshops were a “Conservation Strategy for the Pygmy Hippopotamus” (Mallon et al. 2011) as well as a “National Action Plan for the Conservation of the Pygmy Hippopotamus in Liberia (FFI & FDA 2013). The last general action plan for pygmy hippo conservation had been provided by the IUCN/SSC Pigs, Peccaries and Hippos Specialist Group in 1993 (Eltringham 1993).

Another initiative of the Zoological Society of London was the creation of the “EDGE of Existence Program” (EDGE = Evolutionary Distinct and Globally Endangered). This program ranked pygmy hippos as number 28 of 100 mammal species that had received only limited conservation attention in the past, that show unique evolutionary characteristics and were conservation and research actions are urgently needed (Isaac et al. 2007).

The increasing threats to pygmy hippos and an increased international interest in the plight of this species also led to more projects on national and regional levels

(Mallon et al. 2011, Conway 2013), including transboundary initiatives that partly focused on pygmy hippos whose range crosses several international borders (Figure 1).

In Côte d'Ivoire, research and conservation of pygmy hippos focuses on the Taï National Park. Current work started in 2009 and is supported by the Royal Zoological Society of Scotland (RZSS), the Swiss Center for Scientific Research (CSRS) and IBREAM (Institute for Breeding of Rare and Endangered African Mammals) and works in cooperation with the University of Cocody-Abidjan (Mallon et al. 2011). The aims of the project are to collect information on the distribution of the species throughout the National Park and monitor its population. This information should be used to develop an effective conservation management plan. Second, the project focuses on community sensitization and awareness raising, involving primary schools around the National Park.

In Guinea the N'Zérékoré Forestry Centre and the NGO Sylvatrop developed a long-term pygmy hippo project that started in 2011. Aims of the project are to determine the conservation status of pygmy hippos in the forests in south-eastern Guinea, to collect ecological data, and to build local conservation capacities by training personnel from relevant government agencies and civil society (Mallon et al. 2011).

In Liberia pygmy hippo research and conservation activities have been focusing on Sapo National Park, where pygmy hippos were targeted by a bio-monitoring program initiated in 2001 by FFI and the Forestry Development Authority (FDA) and re-established in 2007 (Vogt 2011). In 2008, FFI and FDA also started to develop a standardized monitoring program for pygmy hippos with ZSL with a focus on camera trapping (Collen et al. 2011). The "Across the River – A Transboundary Peace Park for Sierra Leone and Liberia" project (ARTP) included pygmy hippos as a key landscape species that was one of the focal species in the biodiversity monitoring in the Gola National Forest (Mallon et al. 2011, FFI and FDA 2013, Hillers 2013).

In Sierra Leone, most extensive pygmy hippo research and conservation activities have happened in and around the Gola Rainforest National Park (Klop et al. 2008, Hillers & Muana 2011) and Tiwai Island (Conway 2013). While the work is still ongoing in the area of the Gola Rainforest National Park and will be described in more detail in the next paragraph, the last activities on Tiwai Island happened in 2012, with a collaborative attempt of GRNP, ARTP and the University of Georgia to capture a pygmy hippo in order to conduct radio telemetry research. Previous activities on Tiwai Island led by the University of Georgia started in 2008 and focused on field studies, mainly using camera traps, and environmental education of local communities. Furthermore, pygmy hippo captures with pitfall traps were tested and intense conservation and radio telemetry training was given to local assistants (Conway 2013). Further in the North of Sierra Leone, around the Loma Mountains, a pygmy hippo research and conservation project was initiated by Njala University and ZSL in 2010 (Mallon et al. 2011).

2.7 Previous work on pygmy hippos in and around GRNP

Since 2008 different research and conservation activities focusing on pygmy hippos have been carried out in and around GRNP (Klop et al. 2008, Hillers & Muana 2011, Hillers 2013, Lahai 2013). First activities between 2008 and 2010 focused on surveys in suitable habitats, while activities that started in 2010 in ARTP and later on taken over by GRNP also included questionnaires administered in adjacent communities, more extensive surveys along streams, camera trapping, capture and radio telemetry attempts as well as an intense environmental education program with the development of several education materials (Hillers & Muana 2011, Hillers 2013). Furthermore, collected data were used for predictive range mapping conducted by the Royal Society for the Protection of Birds (RSPB) that have been involved as being responsible for overseeing the research work in ARTP and GRNP.

Pygmy hippos were included as a key landscape species in the biodiversity monitoring program of the ARTP from 2010 to 2013 that aimed at monitoring the distribution, abundance, threats and migratory patterns of these species in the Sierra

Leonean community forest connecting the different parts of GRNP and the Liberian Gola National Forest. A pygmy hippo conservation project sponsored by Basel Zoo from 2010 to 2011 aimed at studying, monitoring and protecting pygmy hippos in collaboration with the Gola Forest Programme (GFP)/GRNP and the local communities. Major results obtained through the application of questionnaires and surveys along streams showed that the current distribution and abundance of pygmy hippos seem to be reduced compared to the past (Hillers & Muana 2011, Hillers 2013). Furthermore, the distribution of pygmy hippos seems to be related to the big streams in the community areas around GRNP, especially along the Moro River bordering with Liberia and the Moa River (Figure 2). So far, only few records of pygmy hippos were ever made inside GRNP (Klop et al. 2008), however, also much more effort was made in order to know the pygmy hippo distribution in the community area.

Human-wildlife conflicts, where pygmy hippos fed in plantations and destroyed crops, were only reported in the area around Tiwai Island, but not around GRNP (Hillers & Muana 2011, Conway 2013). Signs of pygmy hippo hunting seemed rare in the area. However, occasionally pygmy hippos seem to be trapped with traps that actually are targeting other animals and might also be shot when the occasion arises. Furthermore, besides the value of their meat, there are numerous traditional believes related to pygmy hippos and especially to some parts of their body, such as their teeth which gives them further importance for local communities.

Not only based on the comparison of the historic and current distribution map it can be concluded that pygmy hippos are now occupying a smaller range around GRNP and have lower numbers. Also the community questionnaires revealed that people generally believed that pygmy hippos became less, and that possible reasons were the destruction of their habitats, the expansion of settlements and the noise created by power saw operations (Hillers & Muana 2011).

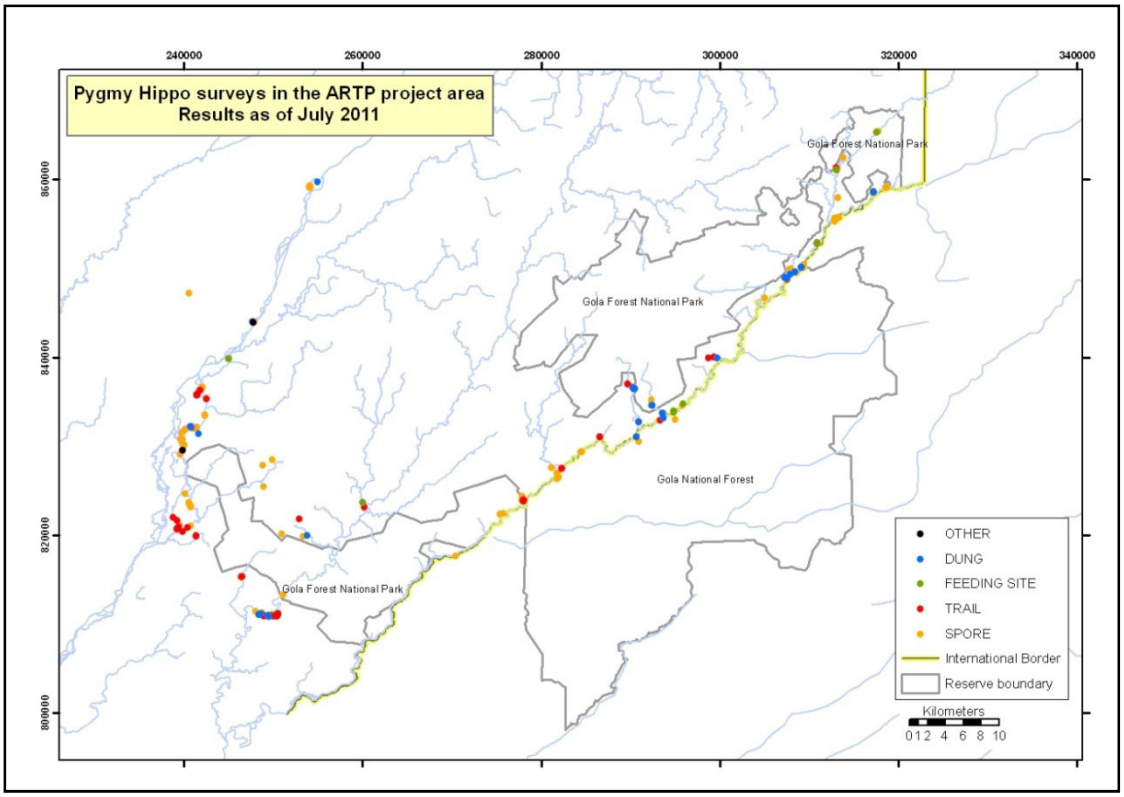

Figure 2: Distribution of pygmy hippos in and around the Gola Rainforest National Park (GRNP), based on records from June 2010 to June 2011 (Hillers & Muana 2011).

The present thesis was conducted in the framework of another research and conservation project being conducted by GRNP from May 2013 to April 2014, again sponsored by Basel Zoo in Switzerland. The present project focuses on five aspects: the survey of water courses and streams inside GRNP, the implementation of new survey designs along focal streams, camera trapping, conservation genetics and environmental education. This thesis focused on the first three of these activities.

Chapter Three

3.0 Methodology

The present study focused on the endangered pygmy hippo (*Choeropsis liberiensis*) in and around the Gola Rainforest National Park in southeastern Sierra Leone. Activities comprised surveys along streams, partly using a newly developed survey design and camera trapping, also with a new survey design. Collected data were compared with the previous distribution data for pygmy hippos in the area.
In the following details will be given about pygmy hippos, the study area and the surveys techniques.

3.1 The study organism pygmy hippopotamus *(Choeropsis liberiensis)*

Different aspects related to pygmy hippos such as their distribution, threats and ecology were already presented in the literature review in Chapter Two. Therefore, this description of the study organism will only focus on few aspects of pygmy hippo biology such as their anatomy and behavior.

The pygmy hippo (Figure 3) is much smaller than the common hippo (*Hippopotamus amphibius*) and weights 180-270 kg. Its shoulder height is 70-80 cm. The limbs and neck of the pygmy hippo are proportionately longer and the head is smaller (Eltringham 1999).

While the common hippo is almost exclusively aquatic, the pygmy hippo also spends considerable times on land and thus has maintained some terrestrial locomotion patterns (Eltringham 1999, Boisserie 2005, Fisher et al. 2007). It is moving through the dense vegetation of swamps, forests and watersides and compared to the common hippo, its toes are only moderately webbed (Robinson 1970). On the other hand, pygmy hippos also have some aquatic adaptations such as strong muscular valves to the ears and nostrils. Furthermore, they are dependent on water in order to cool their bodies as they lack sebaceous glands or temperature regulating sweat glands. Their skin must remain moist as it is very sensitive to sunlight exposure

(Eltringham 1999, Boisserie 2005). Pygmy hippos are able to secrete a clear, oily substance from the pores of their skin. This substance acts as a protection against the sun and might also have antiseptic properties (Eltringham 1999, Hashimoto et al. 2007).

Figure 3: Pygmy hippo captured on camera trap in the community area close to the Gola Rainforest National Park (GRNP) throughout previous surveys in April 2012.

Pygmy hippos are very shy and elusive animals. Therefore, encounters are only rarely reported and only little is known about their behavior and ecology. Robinson (1970), Bülow (1988) and Hentschel (1990) compiled the most comprehensive field reports of pygmy hippos in the past which served as a good foundation for current pygmy hippo work. Eltringham (1999) gave a general description of pygmy biology while a full bibliography was compiled by Robinson (1981). Knowledge about ranging patterns, sizes of home ranges and territoriality of pygmy hippos is very limited. The only home range estimations were made in the 1980s in Côte d'Ivoire (Bülow 1988), when five pygmy hippos (4 females, 1 male) that had been captured in Taï National Park were transferred to Azagny National Park, and radio-collared

and tracked for periods of 3 to 6 months. The estimated home range of a female was 40 to 60 ha, with overlapping ranges, for a male it was 150 ha. Males moved about 2 km per day, females only 900 m (Bülow 1988). Up to date, this remains the only successful radio telemetry study for pygmy hippos.

Pygmy hippos are reported to be solitary, except when having a calf or during the mating period (Robinson 1970, 1996, Robinson & Suter 1999). Activity peaks are at night, but they can also be active during other periods of the day. Radio-collared animals in Azagny National Park were most active between 4 pm and 11 pm (Bülow 1988). Resting periods are often spent hidden in swamps, wallows or hollows under the banks of streams (Roth et al. 2004).

Like other larger mammals, pygmy hippos were observed to follow well-defined trails or tunnel-like paths through the forest and swamp habitat. They mark their trails by spreading their dung through a very fast tail wagging while defecating (Johnston 1906, Robinson 1970).

Pygmy hippo food contains almost exclusively terrestrial and semi-aquatic plants, such as ferns, tender roots, grasses, herbs, stems and leaves of young trees, and if available, vegetables and leaves like sweet potato leaves, okra, pepper, cassava, young rice and fallen fruits (Robinson 1970, 1999, Bülow 1988, Hentschel 1990).

3.2. Study area

The Gola Rainforest National Park (GRNP) is part of the Upper Guinean Forest ecosystem that extends from Guinea to Togo (Figure 4). It ranks among the 25 most important biodiversity hotspots of the world (Myers et al. 2000, Bakarr et al. 2001) and is home to many endemic and threatened animal and plant species (Brooks et al. 2001). The high value of this ecosystem is also reflected by the fact that it is one of WWF's Global 200 Ecoregions (Olson & Dinerstein 1998) and recognized as an Endemic Bird Area by BirdLife International.

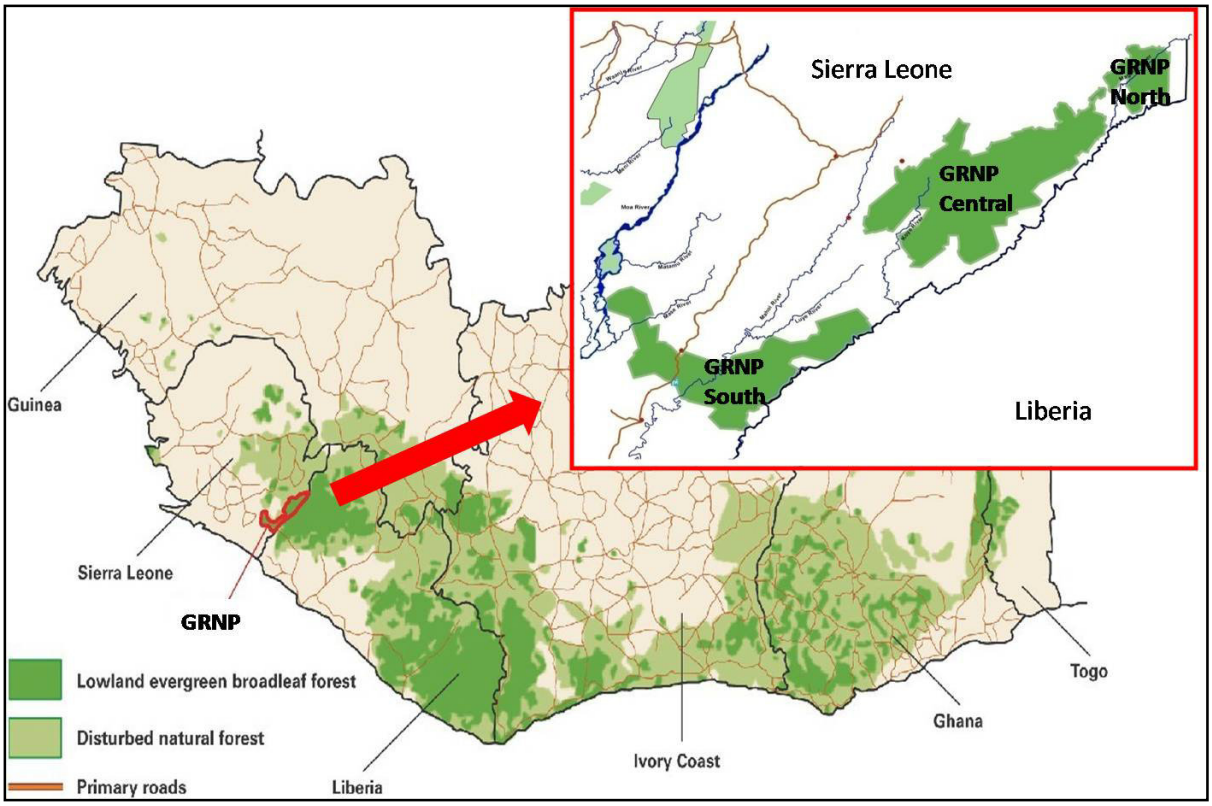

Figure 4: Location of the Gola Rainforest National Park (GRNP) in south-eastern Sierra Leone and the Upper Guinea Forest area, with the three blocks Gola North, Gola Central and Gola South.

The GRNP is located in southeastern Sierra Leone, close to the Liberian border (Figure 4). The GRNP is the largest remaining area of lowland moist evergreen high forest in the country (Lindsell & Klop 2013). It is separated into three forest blocks: Gola North (previously called Extension 2), Gola Central (previously called Gola North) and Gola South (previously called Gola West and East). The total area is 710 km^2, connected by corridors of community forests and farmland that sum up to another 500 km^2. The Moro and Mano Rivers form the boundary to Liberia South of GRNP, other important streams are the Makpoi, Mogbai, Khoye, Kwadi and Mahoi Rivers. GRNP is located in seven Chiefdoms: Malema, Nomo, Tunkia, Gaura, Makpele, Koya and Barrie Chiefdoms. These are located in three districts: Kenema and Kailahun in the eastern province and Pujehun in the southern province. In the

1930s the Gola Forests were gazetted as Forest Reserves (Kop et al. 2008) until the declaration as a National Park in late 2010.

Gola South comprises flatter and swampier areas with a mean altitude of 141 m a.s.l., Gola Central and North are more rugged, with steep slopes, more rocky areas and hills and a mean elevation of 303 m a.s.l. Swamps are restricted to the Mogbai catchment and the floodplains around the Kwadi and Makoi Rivers.

While generally the annual rainfall in the area is mentioned to be 2,500-3,000 mm (Lindsell & Klop 2013), annual rainfall at three sites around GRNP was 3,117 mm in 2007 (Klop et al. 2008). The mean monthly rainfall in 2007 is shown in Figure 5. Rains mostly fall during the rainy season from May to October, with the wettest months being July and August. The dry season lasts from November to April.

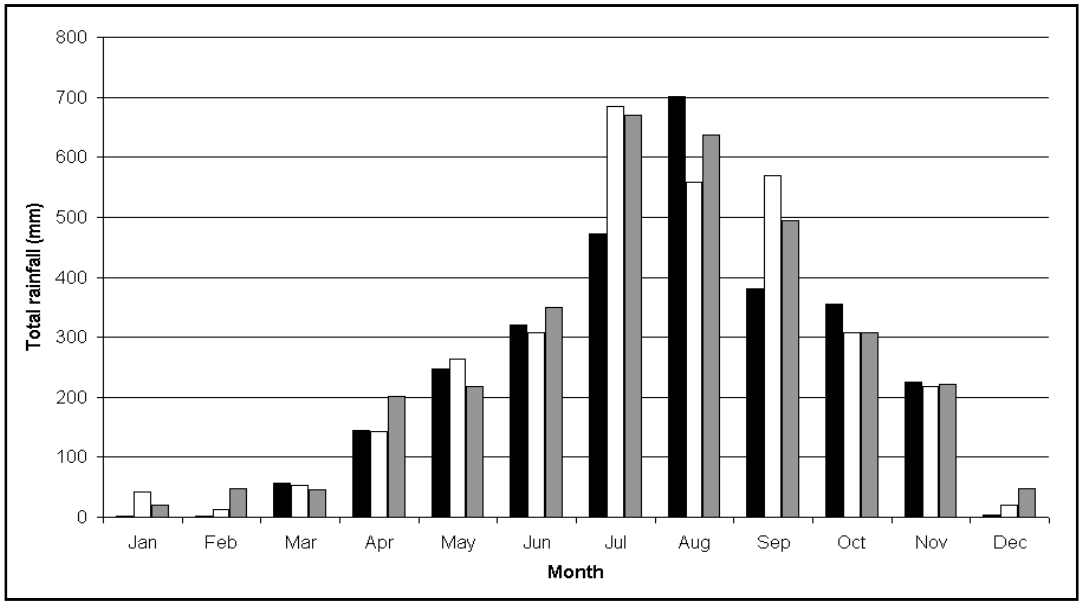

Figure 5: Annual Rainfall measured at three sites in and around the Gola Rainforest National Park (GRNP) in 2007 (from Klop et al. 2008).

About 1,000 species of herbaceous and woody plants are known to occur in GRNP (Klop et al. 2008). Dominant families of woody plants are Leguminosae-Caesalpinoideae, Euphorbiaceae, Leguminosae-Mimosoideae and Sterciliaceae

(Klop et al. 2008). These four families contain 37% of all trees species recorded in GRNP.

Recent faunal surveys in different taxonomic groups confirmed the high species richness and diversity of animals in GRNP (Klop et al. 2008, Hillers 2013). Currently, 327 species of birds, 49 species of large mammals (including nine primate species), 41 bat species, about 30 species of rodents and shrews, 43 amphibian species, 31 fish species, 145 dragon- and damselfly species and 575 butterfly species were reported for the area in and around GRNP throughout different surveys (Klop et al. 2008, Hillers 2013). These include many endemic and threatened species and also numerous first country records for Sierra Leone as well as several species new to science.

3.3 Surveys along streams

Surveys along streams were conducted between May and December 2013. A list of all surveyed streams with names, survey dates and coordinates is given in Appendix 1. Figure 6 shows a map of surveyed streams. In total, 23 streams were surveyed on 44 survey days, sometimes covering different areas along the same stream. Initially, surveys focused only on streams and water courses inside GRNP as one aim of this study was to find out if pygmy hippos are really less common inside GRNP than in the surrounding community areas.

However, other aspects of this thesis project focused on the development and testing of new survey designs for the data collection along streams and for the camera trapping. These should be tested along focal streams with the proven presence of pygmy hippos. Only one stream inside GRNP, the Makoi stream in Gola Central, had sufficient pygmy hippo signs and would have been suitable for the testing of survey designs, as the aim was to test the new designs at more than one stream. Thus, after having surveyed 16 streams inside GRNP with only very few signs, seven streams that were known to harbor pygmy hippos from previous surveys were surveyed outside GRNP.

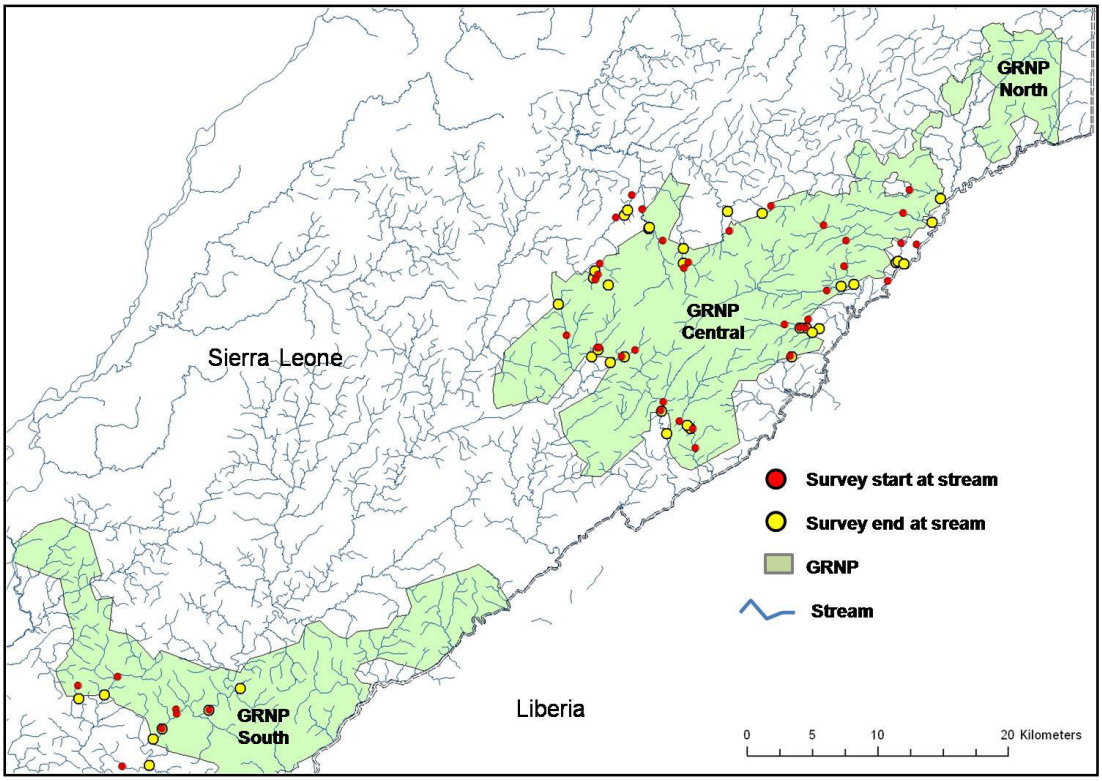

Figure 6: Distribution of streams surveyed in and around the Gola Rainforest National Park (GRNP) on 44 survey days between May and December 2013. Red dots: Start points for daily surveys; yellow dots: end points for daily surveys.

Streams were of different types and sizes, sometimes small and rocky, sometimes bigger and with swampy areas in the surrounding (Figure 7). Also the vegetation type around the streams varied from pristine primary forest to herbaceous plants in swampy areas.

Survey teams consisted of two to three persons who searched for different pygmy hippo signs along streams, such as footprints, dung, trails and feeding sites (Figure 8). Besides the type and location of signs, different variables were recorded, such as the habitat type, the distance to the nearest stream, the width of the stream and the depth of the stream. For each GPS location, the same type of sign was only counted once for further analysis. In case footprints clearly came from different animals (e.g. a mother with a calf), this should be noted.

Figure 7: Examples for two surveyed streams in the primary forest in Gola Central (a) and next to the village Bayama, close to Gola South (b).

Figure 8: Master student Jerry C. Garteh collecting data along stream in Gola Rainforest National (a). Recorded signs are for example pygmy hippo dung that is typically sprayed on the vegetation (b) and pygmy hippo footprints (c).

3.3.1 Surveys along streams without standardized survey design

Pygmy hippos are known to be semi-aquatic animals with a strong preference for streams and swampy areas. As the main interest of previous pygmy hippo surveys in the Gola Forest area was to get a better knowledge about the distribution of pygmy hippos in the area, survey teams targeted different streams in and around the GRNP, especially larger streams which are mainly located in the community areas (Klop et al. 2008, Hillers & Muana 2011). Often based on recommendations from community members about the presence of pygmy hippos, survey teams walked slowly along selected streams and searched for pygmy hippo signs in vicinity to the streams. This allowed the teams to be flexible in following a particular stream and in covering longer distances along streams, e.g. when based on the surrounding habitats or disturbances the presence of pygmy hippos was unlikely and no signs were observed or when obstacles blocked the areas next to a stream. This survey method resembles a reconnaissance survey (Newing et al.2002) as it is not following any standardized survey design and cannot be repeated in the same way by others. Furthermore, as there is no information about any exact area covered, it is not possible to compare any pygmy hippo abundances or densities based on signs at different sites and streams and at different times.

One aim of this study was to investigate if pygmy hippos really do not occur along the streams inside GRNP to the same extent as they occur in the community areas around GRNP. Previous studies found many signs along bigger streams in the community area, especially at the Moro River bordering with Liberia, while signs inside GRNP were only found at two occasions (Klop et al. 2008, Hillers & Muana 2011). On the other hand previous pygmy hippo surveys put much more survey effort into the community areas or exclusively focused on the community area, while no intense study ever focused on pygmy hippos inside GRNP.

This study therefore aimed to conduct surveys along streams inside GRNP. As many streams as possible were surveyed during the study period and partly very long distances were covered along streams. Sixteen streams were surveyed inside GRNP and signs were recorded along the streams as described in the previous

paragraph (3.3) without using any particular survey design, but using a reconnaissance approach (also called recce). At a later stage of the study, seven additional streams were surveyed in the community area outside GRNP as the observations along streams inside GRNP had been too few to test newly developed survey designs. Surveys without standardized design were conducted on 37 survey days.

3.3.2 Surveys along streams with new survey designs

As explained in the previous paragraph (3.3.1), past pygmy hippo surveys in the Gola Forest area did not follow any standardized survey procedures, but were reconnaissance surveys (Newing et al. 2002), and therefore prevent from the possibility to repeat surveys at exactly the same place and in the same way, and also from directly comparing data between different areas or for the same area during different times. Furthermore, it is not possible to define any precise distances or areas covered during surveys, which would be necessary for the calculation of abundances of observed signs (e.g. number of signs per surveyed km or ha). The possibility to quantify the abundance or density of observed signs would also allow for better recommendations for the conservation and management of GRNP, as it would allow for more accurate comparison between areas and priority setting for activities in order to protect the most important areas for pygmy hippos in the best way. Furthermore, it would allow for observing potential changes in the pygmy hippo population over time.

Standardized transect surveys are often used in order to study the distribution, abundance and population size of large mammals, including primates (e.g. Newing et al. 2002). Transects are straight lines of a defined length and are normally evenly distributed within a respective survey area. Recording direct and indirect signs along transects and measuring perpendicular distances allow for the calculation of population sizes and densities for species with sufficient records. However, when using indirect signs, such as dung or nests (for chimpanzees), defecation and decay rates need to be taken into account into the analysis.

Using transects for pygmy hippo surveys does not seem impossible and pygmy hippo signs were also observed occasionally using transects in the Gola Forest area in the past (Hillers 2013) and also were used for studying pygmy hippos in Taï National Park in Côte d'Ivoire (Roth et al. 2004). However, as the distribution of pygmy hippos observed so far is clearly concentrated along streams, exclusively using transect methods would probably lead to overlooking many signs as transects would normally not necessarily follow streams and swamps. Furthermore, it would not be possible to reliably calculate any other value besides the abundance of pygmy hippo signs per surveyed km, as defecation and decay rates for pygmy hippo dung are not known and such values can also not be attributed to any other potentially observed pygmy hippo sign.

In order to get a more comprehensive idea about the distribution of pygmy hippos and their abundance, it was therefore decided to develop a survey design that does not rely on transects, but focuses on streams and can be repeated along the same stream and at different streams in a standardized way.

Based on the results of our survey during the first months of this study, and also taking into account results from previous surveys (Hillers & Muana 2011) two new survey designs were developed and tested. Figure 9 shows the distribution of pygmy hippo signs recorded along the Makoi stream in Gola Central recorded on 9 July 2013 as an example for distances taken into account for the development of the new survey designs. At this and also other surveyed stream, pygmy hippos signs seem to be found within up to 100 m distance from a stream (but most of them being much closer than 100 m) and usually within less than 200 m distance from each other. Furthermore, clusters of pygmy hippo signs often did not cover more than 1.8 to 2 km along a stream, which also is a distance that can realistically be covered within one survey day. For the new survey design, it therefore was decided to aim at covering a distance of 1.8 to 2 km along one stream, focusing on 200 by 100 m plots evenly distributed along the stream. Two designs (designs A and B) were developed and tested.

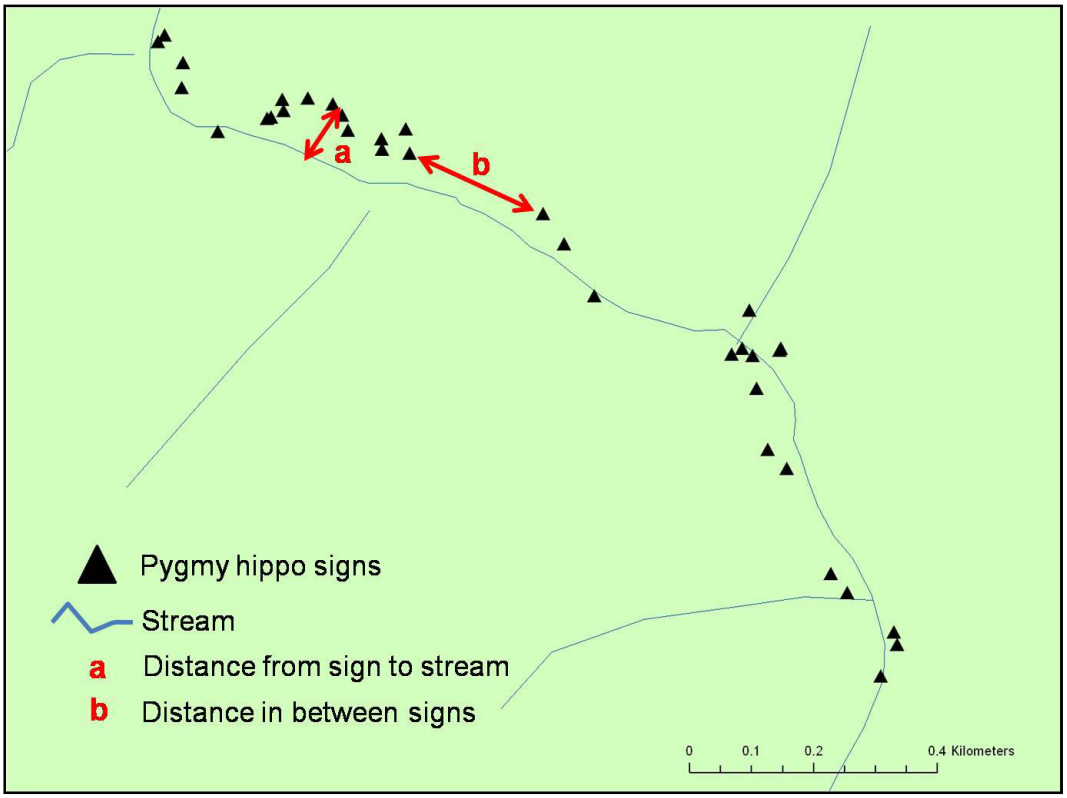

Figure 9: Pygmy hippo records along Makoi stream in Gola Central recorded on 9 July 2013 and examples for measured distances in between pygmy hippo signs and the stream and in between signs.

Design A is presented in Figure 10. In this design, the distance of 2 km along a stream was divided into ten sections (or plots), each measuring 200 by 100 m. Every second section was thoroughly surveyed by teams of two to three persons searching for pygmy hippo signs. In case pygmy hippo signs were observed in between surveyed sections, they were recorded using an opportunistic sampling data sheet that is carried by all GRNP research teams throughout all research activities and is used for any occasional record made outside of actual survey activities.

As Design A covers quite a large area and as thoroughly searching in five 2 ha-sections within one day might be very exhausting, a second design (Design B) was developed, only focusing on five subsections within each section surveyed in Design A. Design B is shown in Figure 11. Again, the same sections are used as in Design A. However, within each section, only five 5 by 5 m plots in a distance of 50 m from

each other are surveyed. The aim was to cover at least the same five sections as in design A, thus covering at least 25 of the 5 by 5 m plots per day. In case this method proved to be faster than Design A, as a much smaller area is thoroughly surveyed, potentially a longer distance along a respective stream could be surveyed, adding more sections to the initial five. As in Design A, any signs found in between surveyed plots were recorded using the Opportunistic Sampling data sheet. Ideally, for direct comparisons of designs, both survey designs should have been tested exactly along in the same area along the same stream. However, due to logistical constraints and delays caused by community people denying access to part of the study area, Design A was only tested on three survey days and Design B on four survey days.

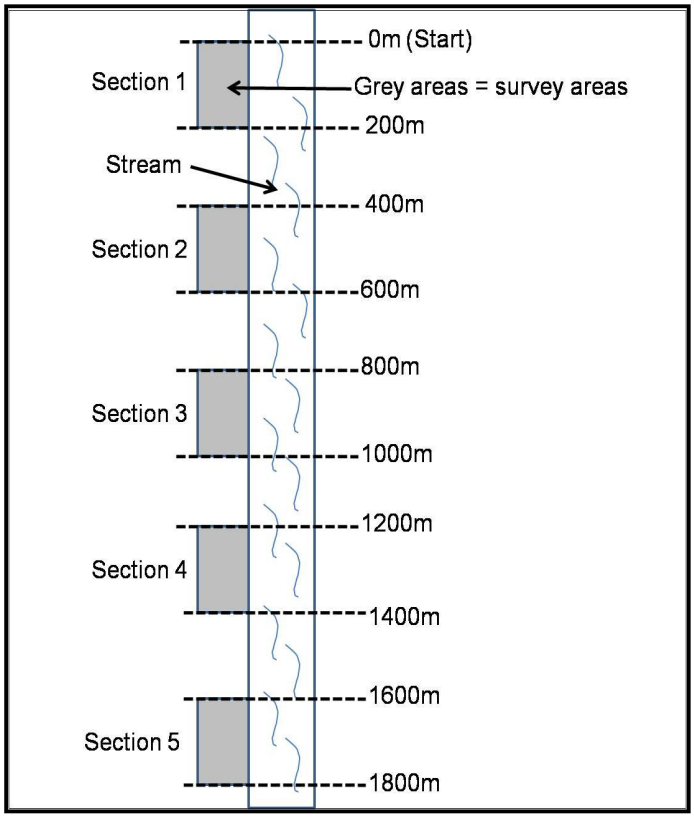

Figure 10: Newly developed survey Design A, covering about 1.8 km distance along a stream. This distance is divided into ten sections of 200 by 100 m, of which every second section, thus five sections in total, is surveyed for pygmy hippo signs.

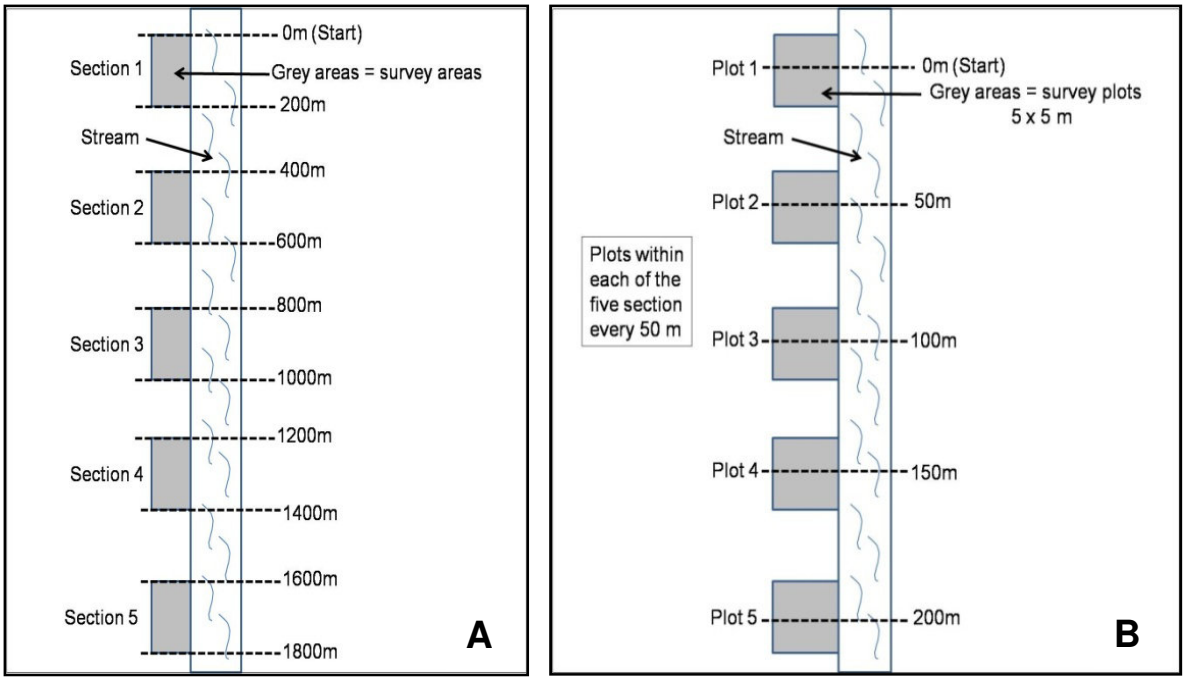

Figure 11: Newly developed survey Design B, covering about 1.8 km distance along a stream. This distance is divided into ten sections of 200 by 100 m (as in Design A). Within each section five plots of 5 by 5 m size are surveyed for pygmy hippo signs (B), thus covering 25 plots.

3.4 Camera trapping with new design

Since the start of the pygmy hippo work in and around GRNP, only a few pygmy hippos have been recorded by camera traps. During an extensive camera trapping survey from 2011 to 2013, covering 194 plots in and around GRNP for at least 21 days each, only two pygmy hippos were recorded; one of them at the Makoi stream inside GRNP (Hillers 2013). However, this standardized camera trap survey focused on all terrestrial mammals and birds and did not particularly focus on streams potentially occupied by pygmy hippos.

As knowledge about the presence of different individuals of a species in a respective area is important for estimations of population sizes and home ranges, an attempt was made to obtain camera trap pictures from different individuals of pygmy hippos.

Following the newly developed survey designs for the surveys along streams, also the camera trapping design focused on 200 m intervals. Within a total distance of 1.8 km along a stream, ten cameras should be deployed every 200 m. However, there was a certain flexibility by allowing for deployment in a 100 by 200 m plot around the actual 200 m distance, in case any pygmy hippo sign (such as trails and footprints) were observed in this area. In case no pygmy hippo sign was observed, the camera was placed exactly in a 200 m distance from the next camera. The new camera trapping design is shown in Figure 12.

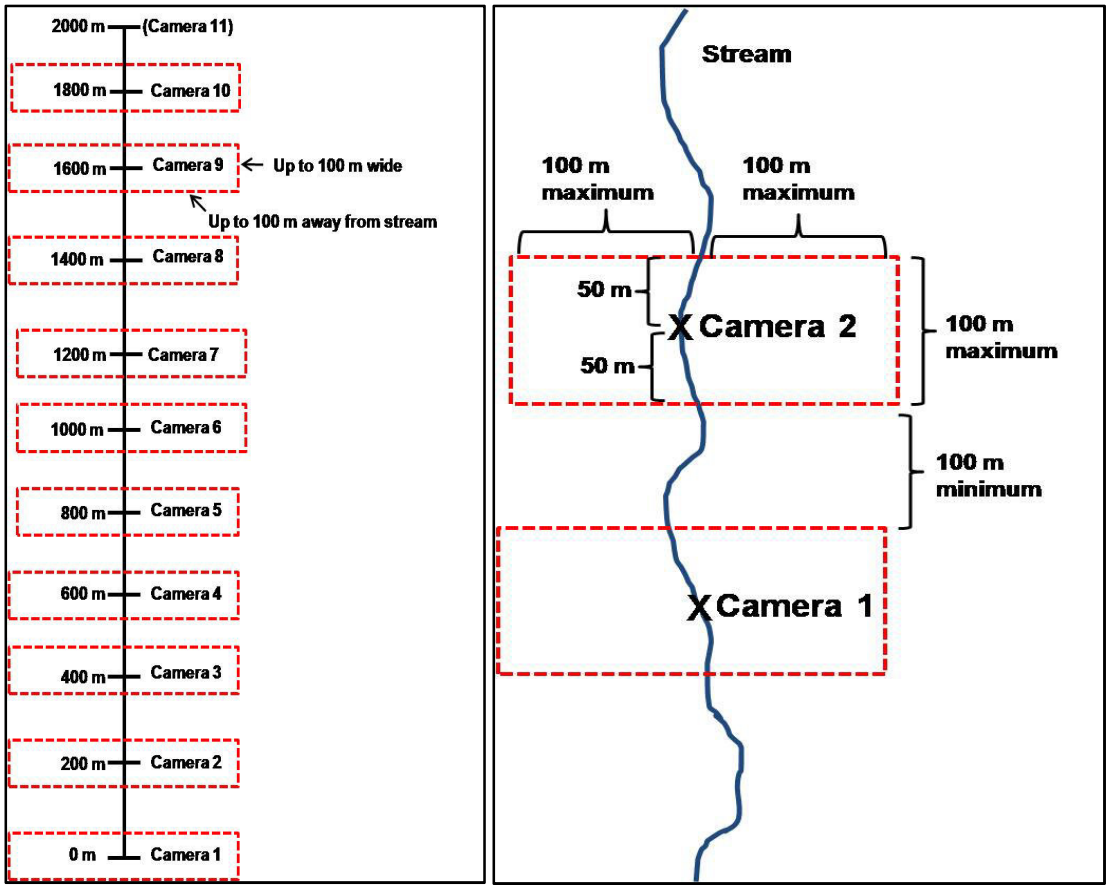

Figure 12: New design for the camera trap deployment targeting pygmy hippos, covering about 1.8 km along a stream with camera traps being deployed in 200 m distance.

The Makoi stream in Gola Central (Figure 9) seemed to be the ideal test stream for the new camera trapping design, as the presence of pygmy hippos had been proven at several occasions, including during this study, and also a camera trap picture of a pygmy hippo had been obtained in the past (Hillers 2013). Additionally, the stream is located in a remote area inside GRNP which would have reduced the chances of human disturbance during camera trapping. However, when almost reaching to the stream, access was denied by adjacent communities, due to issues not related to the current study or any research activity and being beyond the influence of the research team. Thus, an alternative test stream had to be selected at short notice. Based on records from previous studies (Hillers & Muana 2011) and based on easy and fast accessibility, it was decided to shift the testing of the camera trapping to the Mahoi stream, close to the village Bayama and Gola South. A map of the area with locations of deployed camera traps is shown in Figure 13.

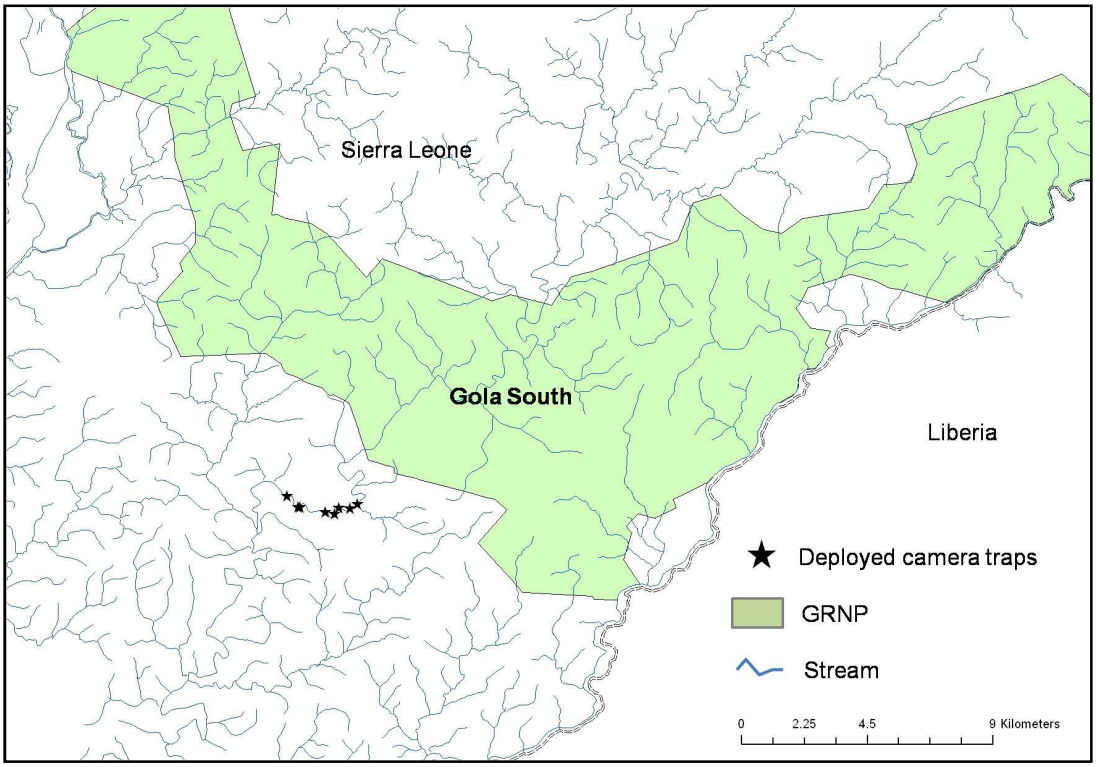

Figure 13: Location of deployed camera traps along Mahoi River close to Gola South. Camera traps were deployed from 30 October to 3 December 2013.

From 30 October to 2 December eight camera traps (Reconyx PC800 Hyperfire) were deployed along the Mahoi River (Figure 13 and 14). Due to the high presence of humans and the high level of human activities such as farming and fishing, it was not possible to cover 1.8 km along the river and to deploy ten cameras as planned. A list of deployed cameras with locations as well as deployment and collection dates and times is given in Appendix 2. In total, the deployment time for all eight cameras together was 263.91 days.

Figure 14: Deployed camera trap next to the village Bayama and Gola South.

All GPS coordinates shown in this thesis were recorded using handheld GPS units (Garmin 60Cx). Distances to streams were measured using measuring tapes. Maps of surveyed streams, deployed camera traps and observed signs were compiled using the software ArcGIS 10.1.

Chapter Four

4.0 Result

In the following the results from the surveys along the streams, using the reconnaissance survey method, the newly developed survey designs and opportunistic sampling, and the results from the camera trap survey will be presented.

4.1 Results from surveys along streams

In total, 23 streams were surveyed, 16 inside GRNP and seven in the adjacent community areas. During these surveys that happened on 44 survey days, 56 pygmy hippo signs were recorded in total, 48 during the actual surveys along streams, seven resulting from the opportunistic sampling. At each GPS location, each type of sign was counted only once. A map with the distribution of signs is given in Figure 15, also showing the surveyed streams. Recorded signs were either pygmy hippo trails, footprints, dung or feeding sites. A list of all recorded signs with the respective type of sign, date and location is given in Appendix 3. Most recorded signs were trails (30, 53.6%), followed by footprints (22, 39.3%), dung (3, 0.05%) and feeding sites (1, 0.01%). By far the most signs were observed along the Makoi stream inside GRNP (33 signs, 69% of signs recorded throughout actual surveys), but these were the only signs recorded inside GRNP. The other signs were recorded on four other streams: Moro (6 signs, 12.5%), Lewei and Mahoi (4 signs, 8 %, respectively) and Mamawa (1 sign, 2%).

Out of the 48 signs recorded during surveys along streams, only six (12.5%) were recorded using the new survey designs. However, because of logistic constraints and related delays, the new survey designs were only tested on seven out of 44 survey days (16%).

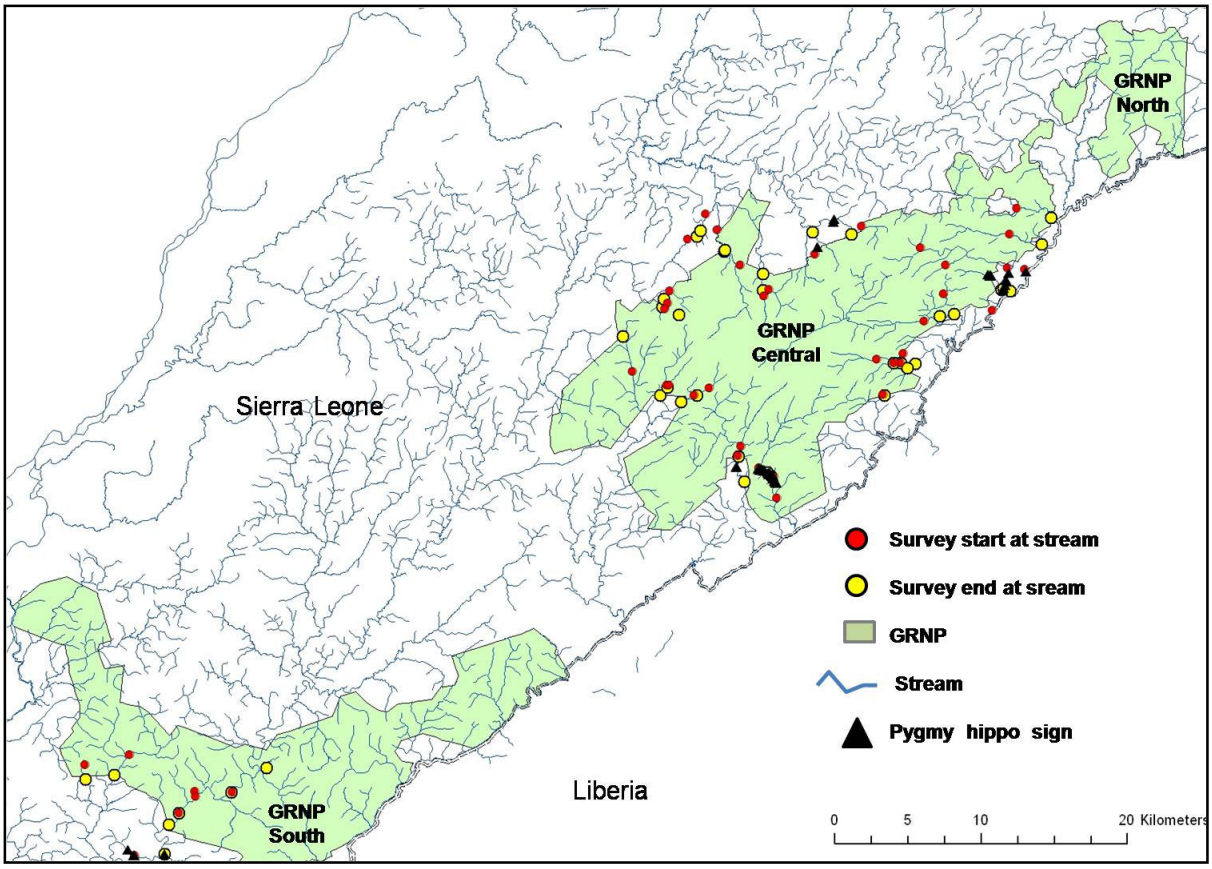

Figure 15: Distribution of observed pygmy hippo signs throughout surveys along streams and opportunistic sampling.

Previous pygmy hippo surveys conducted in the community area around GRNP from 2010 to 2011 (Hillers & Muana 2011) exclusively used reconnaissance surveys. On 93 survey days 415 pygmy hippo signs were detected in the community areas, especially being located along big streams (Figure 2). Previous data and data from this study are not directly comparable without taking into account the number of observers and the survey time for each survey date. As this information is not available for all survey days of both studies, only a rough comparison can be made based on the relative number of signs observed per survey day. For the previous study, the relative encounter rate of signs was 4.46 signs per survey day (415 signs on 93 survey days), for the present study it was 1.09 signs per survey day (48 signs on 44 survey days, not taking into account records made throughout the opportunistic sampling). Though this is only a rough indication and direct comparison

cannot be made without additional information, as explained above, based on these figures, the encounter rate of pygmy hippo signs in the community area was about four times as high for the survey conducted from 2010 to 2011 (Hillers & Muana 2011) as it was in the present study.

4.2 Results from camera trapping

The deployed camera traps recorded 11 species of small and large mammals during a total deployment time of 263.91 days for the eight cameras together. A list of recorded mammals is given in Table 1. No pygmy hippo was recorded with the camera traps, but five cameras took pictures of persons (C1, C5, C28, C29, C30), some of them numerous pictures, indicating a high level of human disturbance in the deployment area.

Table 1: List of mammals recorded throughout camera trapping between 30 October and 3 December 2013.

Family	Species		Camera trap record
	Common name	Scientific name	
Primates			
Cercopithecidae	Sooty Mangabey	*Cercocebus atys*	C29, C30
	Campbell's monkey	*Cercopithecus campbelli*	C2, C23, C28
Rodents			
Sciuridae	Fire-footed rope squirrel	*Funisciurus pyrropus*	C1, C28
Hystricidae	Brush-tailed porcupine	*Atherurus africanus*	C2
Nesomyidae	Forest Giant Pouched Rat	*Cricetomys emini*	C1, C29
Mongooses			
Herpestidae	Marsh mongoose	*Atilax paludinosus*	C1, C4, C23
Civets			
Viverridae	African Civet	*Civettictis civetta*	C2, C4
Nandiniidae	African Palm Civet	*Nandinia binotata*	C1, C28
Scaly Ant-eaters			
Manidae	White-bellied Pangolin	*Phataginus tricuspis*	C2
Chevrotains			
Tragulidae	Water Chevrotain	*Hyemoschus aquaticus*	C29
Bovids			
Bovidae	Bushbuck	*Tragelaphus scriptus*	C28

Chapter Five

5.0 Discussion and Recommendations

Pygmy hippos are rare and elusive animals and though research and conservation efforts have increased in their four range countries Sierra Leone, Liberia, Côte d'Ivoire and Guinea over the last years, there is still lack of knowledge concerning different aspects especially of their ecology and behavior.

Since 2008, different surveys and conservation efforts are targeting pygmy hippos in and around the Gola Rainforest National Park (GRNP) in south-eastern Sierra Leone (Klop et al. 2008, Hillers & Muana 2011, Hillers 2013). Intense reconnaissance surveys conducted from 2010 to 2011 focused on community areas around GRNP and the presence of pygmy hippos was observed especially along big streams, such as the Moro River at the Liberian border (Hillers & Muana 2011). Previous surveys (Klop et al. 2008) also indicated that pygmy hippos might be more common in the community areas outside GRNP than inside the protected area. However, no survey ever focused on surveying streams for pygmy hippos inside GRNP.

Second, no standardized survey techniques were used when conducting pygmy hippo surveys in the past and research relied on reconnaissance surveys. Thus, it has not been possible to directly compare data from different areas, or to repeat surveys in the same area and compare data from different times which would allow for the detection of potential changes in the distribution and abundance of pygmy hippos. On the other hand, this knowledge would be very important for an effective management and protection of pygmy hippos and their habitats.

Finally, so far there was no possibility to distinguish different individuals of pygmy hippos which would help to get an idea about how many individuals occur in a particular area. Such knowledge would be necessary in order to make estimates of population sizes.

Therefore, this thesis focused on three aspects: i) surveys along streams inside GRNP in order to find out if pygmy hippos are really more common outside GRNP than inside – which would also have important management implications in order to assure effective protection of this species in the area; ii) the development and testing of new designs for surveys along streams in order to have a standardized and repeatable design for future surveys; iii) camera trapping, also using a new design, in order to test if different individuals of pygmy hippos can be distinguished based on camera traps in a defined area.

In the following the results obtained in this study will be discussed under the different aspects explained above and recommendations will be given for future research and conservation activities related to pygmy hippos in and around GRNP.

5.1 Distribution of pygmy hippos in and around GRNP

Though not all streams inside GRNP were studied throughout the present study, surveys along 16 streams inside GRNP found pygmy hippo signs only at one stream (Makoi stream in Gola Central), which however is partly surrounded by swampy areas and open and herbaceous vegetation. When making a rough comparison of signs encountered per survey day in the present study compared with a previous survey that focused on community areas (Hillers & Muana 2011), the encounter rate of pygmy hippo signs was about four times as high in the community areas in 2010/2011 as it was in the present study. Also the comparisons of the distribution maps compiled in the previous and the present survey (Figures 2 and 15) support the idea that pygmy hippos are more common in the community areas around GRNP than inside the protected area.

The known distribution of pygmy hippos in the GRNP area suggests that the presence of larger streams and swampy areas with partly herbaceous vegetation, including potential food plants, are of high importance for pygmy hippos. In the case of GRNP, pygmy hippos seem to avoid rocky and hilly areas that are especially characteristic for Gola Central and Gola North, though many streams of different

sizes can be found in these areas as well. The topography of the area and the presence of bigger streams thus seem to play an important role for the presence or absence of pygmy hippos in the Gola Forest area. This result is different from Roth et al. (2004) who suggest that the presence of rivers or the availability of herbaceous food plants play a minor role for the habitat preference of pygmy hippos. In Taï National Park, pygmy hippos seem to be mainly dependent on the presence of small streams with submerged trees, root hollows, and swampy depressions. Many small streams exist inside GRNP, but the terrain might be too rocky and too hilly and streams might be too shallow to provide appropriate hiding places for pygmy hippos.

Additionally, the observation of several signs of human activities at least along some of the surveyed streams might further contribute to low encounter rates of pygmy hippo signs inside GRNP. Despite continuous patrols of GRNP rangers, poachers are still present in different parts of the forest and especially in Gola South, many fishermen were observed along streams. While in the case of GRNP fishing is allowed for local communities inside the National Park (without using poison and following rules concerning mash sizes), the presence of fishermen might disturb pygmy hippos. However, fishermen are even more common in the community area, where even higher abundances of pygmy hippos were observed.

The presence of humans likely also influenced the results of the camera trapping survey in this study. Pictures of humans were recorded on five out of eight camera traps, sometimes with hundreds of pictures of persons who spent significant times in front of the cameras. Such level of anthropogenic disturbance certainly must have prevented pygmy hippos from coming closer to the camera traps.

Mallon et al. (2011) report that pygmy hippos are mainly found inside protected areas throughout their range. Our results suggest that for all protected areas, future surveys should also focus on surrounding community areas, especially if bigger streams and swamps are located outside the protected areas. In the case of GRNP, even though pygmy hippos are more abundant in the community area, it is likely that

the GRNP is still significantly contributing to the protection of this species. Probably, that without the existence of GRNP the whole area of the Gola Forests would be much more degraded and farming activities and present communities would have a much more serious affect on pygmy hippos. It is likely that the overall still forested landscape is contributing to the survival of pygmy hippos. In fact, in areas with less overall forest cover and higher agricultural pressure, more conflicts such as human-wildlife conflicts mentioning encroachment by pygmy hippos are reported. This is for examples the case around Tiwai Island (Hillers & Muana 2011, Conway 2013) where the natural habitat of pygmy hippos is very much reduced and farming is happening even on smaller islands in the Moa River that used to be pygmy hippo habitats. Here pygmy hippos are reported to occasionally enter farms and feed on and destroy crops such as sweet potato leaves and young rice.

The findings of the present study thus have also important implications for the management of GRNP as environmental education activities as well as livelihood support need to include knowledge and conservation of pygmy hippos. Agricultural activities with communities need to include knowledge about present pygmy hippo habitats in land use planning exercises.

5.2 New survey designs

Both newly developed survey designs were tested, however only on seven out of 44 survey days. Furthermore, it would have been necessary to test both survey designs at exactly the same location, in order to find out if both designs are effectively recording present pygmy hippo signs. Due to logistic constraints and delays, it was not possible to test the designs more often. As signs were only recorded with design B and only in a very low number, it would be premature to judge the quality of either of the two designs. However, given that defined areas are covered that are distributed along streams in a standardized way, both designs are repeatable and allow for calculation of numbers of pygmy hippo signs in a given area which allows for the comparison of different areas as well as of different times for the same area. The developed survey techniques thus also would enable researchers to observe

changes in abundances of pygmy hippo signs over time or to identify priority areas for conservation based on the number and density of observed pygmy hippo signs.

In terms of the ease of application of the two designs, though a much larger area is covered, design A seemed to be preferable. This is due to the fact that measuring the 50 m distances of 25 plot centres from each other was very tedious while surveying five 2 ha plots for pygmy hippo signs without additional measurements of smaller plots was easier for the survey team.

5.3 Recommendations

In the following, based on the results and observations made throughout this study, different recommendations will be given concerning i) future pygmy hippo research activities and ii) future conservation measures in GRNP.

5.3.1 Recommendations for future pygmy hippo research activities

Future research activities should include all activities undertaken in this thesis, in order to get more robust results and to increase our knowledge beyond the current status. There are still several streams inside GRNP that based on their size might be suitable pygmy hippo habitats. Some of them were already surveyed in the present survey, but were flooded during the rainy season and potential pygmy hippo signs might have been washed away. It thus is recommended that more streams are surveyed during the dry season.

The two survey designs A and B needs further testing. It is necessary to test them at exactly the same place in order to evaluate their effectiveness and also in order to get more experience with their application before a final decision can be taken about how good one design is compared to the other or if a different design needs to be developed. Future surveys should, if possible, attempt to use a standardized design, for reasons of repeatability and comparability. Also, only standardized designs will allow for the calculation of abundances and densities.

The camera trapping survey should be continued preferably focusing on streams with known pygmy hippo presence, but in remote areas where the presence of humans who are regularly visiting the camera traps can be excluded. Future camera trapping surveys might allow for the distinction between individuals, though camera trapping on Tiwai Island only allowed for the recognition of one female pygmy hippo that obviously had an eye injury. For other pygmy hippos recorded by camera traps no individual identification was possible (Conway 2013).

Distinguishing different individuals of pygmy hippos would be essential for the estimation of the population size of pygmy hippos in and around GRNP and also for the estimation of their home ranges. Another possible attempt is genetic fingerprinting using DNA analysis from dung samples. GRNP already started collaborating with Chester University and the RZSS on conservation genetics. However, throughout the last months only two dung samples were collected and more effort should be made in order to collect more dung samples. Sampling should especially be done during the dry season because pygmy hippo dung is watery and mostly sprayed on leaves and the surrounding vegetation, from where it can easily be washed away by rainfall and flooded streams.

Also for the actual field work some recommendations should be given. It is my personal impression that hunters from communities that are recruited as assistants for research activities are using the information collected throughout the research for their hunting activities. I therefore recommend that even if hunters usually are those community members with the best knowledge about the forest, other community members that are not hunting should be selected as assistants for research activities. One solution could also be to recruit permanent guides from communities (that are not hunters).

While it is very important that researchers have good relationships and collaborations with communities, it should be avoided to pass on sensitive information to community members such as about territoriality and feeding habits or

to show particular areas where camera traps recorded particular animals (e.g. animals targeted by hunting for bushmeat), especially in the community area.

5.3.2 Recommendations for future conservation measures in GRNP

The Gola Rainforest National Park should continue the collaboration with communities around GRNP, especially in areas with high abundances of pygmy hippos. Activities that support communities, such as livelihood support, should continue, given that activities are not affecting pygmy hippo habitats.

Knowledge about the distribution patterns of pygmy hippos should be included in land use planning exercises with communities, especially when GRNP is supporting communities for agricultural activities, such as Inland Valley Swamp Farming.

Ongoing environmental education activities should continue to include awareness raising about pygmy hippos, their status and their importance for the ecosystem.

Finally, future research activities should continue to include pygmy hippos as a key landscape species.

Acronyms

ARTP	Across the River – A Transboundary Peace Park for Sierra Leone and Liberia project
asl	above sea level
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CSRS	Swiss Center for Scientific Research
FDA	Forestry Development Authority
FFI	Fauna and Flora International
GoSL	Government of Sierra Leone
GFP	Gola Forest Programme
GPS	Global Positioning System
GRNP	Gola Rainforest National Park
IBREAM	Institute for Breeding of Rare and Endangered African Mammals
IUCN	International Union for the Conservation of Nature
NBSAP	National Biodiversity Strategy and Action Plan for Sierra Leone
NGO	Non Governmental Organisation
RSPB	Royal Society for the Protection of Birds
RZSS	Royal Zoological Society of Scotland
SSC	Species Survival Commission
ZSL	Zoological Society of London

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Appendix 1

List of surveyed streams with survey dates, times, start and end coordinates and number of observed pygmy hippo signs. Coordinates are in UTM 29 N.

Name of Stream	Date	Start time	End time	Start coordinates		End coordinates		No. of observed pygmy hippo signs
				x	y	x	y	
Lewei	15.05.2013	09:08	na	307860	849824	304048	851479	4
Lewei	15.05.2013	09:08	na	307860	849824	302324	852654	0
Kpoyewa	16.05.2013	08:15	na	310621	852912	308381	853601	0
Kpoyewa	16.05.2013	10:28	na	311262	854710	308874	855337	0
Mogbai	16.05.2013	12:14	na	304595	848113	302564	847649	0
Wekwa	18.05.2013	13:40	na	303619	847967	303889	849525	0
Hojoyea (Branch)	30.05.2013	08:33	13:02	284681	848601	284984	848875	0
Tekuyei	30.05.2013	10:03	14:40	281948	846628	282610	844193	0
Weisugbu	31.05.2013	08:12	16:22	285784	848083	285156	849693	0
Hojoyea (Main)	07.06.2013	07:49	14:30	284767	849161	284835	848491	0
Wowei (Upper)	08.06.2013	10:45	16:55	288873	852429	289977	851459	0
Wulor (Main stream)	08.06.2013	10:30	12:40	291551	850877	291952	849793	0
Wulor (branch)	09.06.2013	11:23	11:56	291548	849758	291602	849350	0
Wowei (Lower)	09.06.2013	10:46	14:40	288920	852505	288376	853904	0
Mamawa	11.06.2013	09:34	17:03	294952	853731	295098	852211	1
Mamawa	11.06.2013	13:46	15:10	297577	853576	298281	854141	0
Kwadi	07.07.2013	10:34	14:14	289855	838389	290008	839107	0
Kwadi	07.07.2013	10:54	15:35	290291	836678	289828	838454	0
Makoi (Upper)	09.07.2013	10:38	15:15	291848	837332	291254	837601	15
Makoi (Lower)	09.07.2013	09:02	17:38	292082	837087	292482	835535	14
Makoi (Lower)	10.07.2013	10:33	13:21	291832	837315	292275	837020	4

Name of Stream	Date	Start time	End time	Start coordinates		End coordinates		No. of observed pygmy hippo signs
				x	y	x	y	
Kondehua	26.07.2013	12:31	15:22	285943	842123	286841	842577	0
Koyei (Wayeihun)	26.07.2013	13:26	16:19	284505	842583	284970	843250	0
Koyei (tributary)	27.07.2013	12:29	15:49	284999	843134	285090	843283	0
Kondehua 2	27.07.2013	12:49	16:14	287042	842573	287850	843061	0
Wegbua 1	19.08.2013	12:02	14:45	301972	844763	300948	844771	0
Wegbua 2	20.08.2013	12:51	15:32	300957	844774	301142	845409	0
Wegbua 3	21.08.2013	11:25	15:23	301436	844432	300480	844772	0
Wegbua 4	22.08.2013	12:24	16:12	300480	844789	299312	845055	0
Weisei	22.08.2013	14:33	14:58	299865	842598	299745	842636	0
Mahoi	12.10.2013	11:34	17:09	250904	813234	251608	814004	0
Mahoi	13.10.2013	09:11	16:02	251609	814013	252711	815165	0
Mahoi	14.10.2013	11:38	17:25	257606	817120	255206	815439	0
Mahoi 4	15.10.2013	09:27	16:53	255199	815448	252684	815478	0
Nyeiyea	17.10.2013	09:38	15:36	245182	816315	245170	817318	0
Yambaseh	18.10.2013	09:53	17:02	247144	816630	248185	817983	0
Mahoi	30.10.2013	11:00	12:49	250622	811236	248564	811129	4
Wobia	09.11.2013	11:26	13:14	287021	853432	287636	854973	0
Moro	18.11.2013	09:00	13:47	308453	849701	309446	851196	1
Moro	19.11.2013	09:26	11:35	308462	849690	307221	848399	0
Moro	20.11.2013	09:31	14:27	307987	849886	308232	851274	5
Weisukpu	09.12.2013	11:06	14:11	287253	853819	286368	853237	0
Makpoi	14/12/2013	10:09	16:05	313455	861224	314264	862164	0
Makpoi	15/12/2013	08:00	18:45	313458	861219	314243	862158	0

Appendix 2

List of deployed camera traps with deployment and collection dates and times, coordinates and type of observed signs of pygmy hippos at deployment (if any). Coordinates are in UTM 29 N.

Camera No.	Deployment date	Deployment time	Collection date	Collection time	Coordinates		Sign used
					X	Y	
30	30.10.2013	11:40	02.12.2013	15:06	250622	811236	Trail
4	30.10.2013	12:24	02.12.2013	14:35	250358	811067	none
2	30.10.2013	13:35	02.12.2013	13:37	249974	811103	Trail
28	30.10.2013	14:18	02.12.2013	13:02	249801	810876	none
29	30.10.2013	14:58	02.12.2013	12:09	249476	810950	none
1	31.10.2013	11:40	03.12.2013	12:00	248104	811528	Trail
5	31.10.2013	12:36	03.12.2013	12:48	248496	811121	Trail
23	31.10.2013	13:02	03.12.2013	13:16	248564	811129	Trail

Appendix 3

List of pygmy hippos signs observed throughout surveys along streams, using recce and newly developed methods, and throughout opportunistic sampling, with dates and coordinates. Coordinates are in UTM 29 N.

Date	Type of sign	Coordinates		Sampling method
		x	y	
15.05.2013	Footprints	306938	850819	Reconnaissance
15.05.2013	Footprints	307061	850751	Reconnaissance
15.05.2013	Trail	307113	850789	Reconnaissance
15.05.2013	Trail	307081	850776	Reconnaissance
11.06.2013	Footprints	295259	852726	Reconnaissance
09.07.2013	Trail	291650	837410	Reconnaissance
09.07.2013	Trail	291644	837449	Reconnaissance
09.07.2013	Trail	291606	837416	Reconnaissance
09.07.2013	Trail	291550	837447	Reconnaissance
09.07.2013	Trail	291541	837471	Reconnaissance
09.07.2013	Trail	291526	837489	Reconnaissance
09.07.2013	Trail	291446	837479	Reconnaissance
09.07.2013	Trail	291426	837468	Reconnaissance
09.07.2013	Trail	291420	837466	Reconnaissance
09.07.2013	Feeding site	291444	837497	Reconnaissance
09.07.2013	Trail	291340	837445	Reconnaissance
09.07.2013	Trail	291281	837516	Reconnaissance
09.07.2013	Trail	291283	837556	Reconnaissance
09.07.2013	Fresh dung	291254	837601	Reconnaissance
09.07.2013	Trail	291243	837590	Reconnaissance
09.07.2013	Footprints	292249	837091	Reconnaissance
09.07.2013	Trail	292251	837094	Reconnaissance
09.07.2013	Trail	292260	836899	Reconnaissance
09.07.2013	Footprints	292171	837084	Reconnaissance
09.07.2013	Footprints	292188	837094	Reconnaissance
09.07.2013	Footprints	292229	836930	Reconnaissance
09.07.2013	Footprints	292211	837029	Reconnaissance
09.07.2013	Trail	292331	836729	Reconnaissance

Date	Type of sign	Coordinates		Sampling method
		x	y	
09.07.2013	Footprints	292205	837082	Reconnaissance
09.07.2013	Trail	292200	837155	Reconnaissance
09.07.2013	Trail	292439	836615	Reconnaissance
09.07.2013	Footprints	292358	836698	Reconnaissance
09.07.2013	Trail	292433	836635	Reconnaissance
09.07.2013	Footprints	292412	836563	Reconnaissance
10.07.2013	Trail	291604	837433	Reconnaissance
10.07.2013	Trail	291966	837312	Reconnaissance
10.07.2013	Dung	291900	837263	Reconnaissance
10.07.2013	Footprints	291949	837179	Reconnaissance
30.10.2013	Footprints	250622	811236	Reconnaissance
30.10.2013	Trail	248104	811528	Reconnaissance
30.10.2013	Trail	248496	811121	Reconnaissance
30.10.2013	Trail	248564	811129	Reconnaissance
18.11.2013	Footprints	309523	851037	Design B
20.11.2013	Footprints	307987	849886	Design B
20.11.2013	Footprints	307964	849773	Design B
20.11.2013	Footprints	308105	850114	Design B
20.11.2013	Trail	308151	850461	Design B
20.11.2013	Footprints	308151	850461	Design B
11.06.2013	Trail	296355	854440	Opportunistic
11.06.2013	Footprints	296403	854606	Opportunistic
07.07.2013	Trail	289730	837688	Opportunistic
07.07.2013	Footprints	289715	837721	Opportunistic
20.11.2013	Trail	308156	850442	Opportunistic
20.11.2013	Dung	308167	850509	Opportunistic
20.11.2013	Footprints	308167	850509	Opportunistic
20.11.2013	Footprints	308334	850922	Opportunistic