CONSERVATION OF THE PYGMY HIPPOPOTAMUS (*Choeropsis liberiensis*) IN SIERRA LEONE, WEST AFRICA

by

APRIL LEANNE CONWAY

(Under the Direction of John P. Carroll and Sonia M. Hernandez)

ABSTRACT

The pygmy hippopotamus (Choeropsis liberiensis, hereafter pygmy hippo) is an endangered species endemic to the Upper Guinea Rainforests of West Africa. Major threats to their continued survival include poaching for meat and deforestation. With increasing human populations and subsequent land use changes, pygmy hippo survival is far from certain. Understanding their ecology and behavior requires knowledge of the anthropogenic forces that influence them. I report on a study conducted on and around a protected area, Tiwai Island Wildlife Sanctuary, in southeastern Sierra Leone. The objective of this research was to explore local knowledge about pygmy hippos and human-wildlife interactions, test radio transmitter attachment methods, evaluate physical capture methods for radio transmitter attachment, and explore the use of camera trapping to determine occupancy and activity patterns of pygmy hippos. My results suggested that while the majority of local residents in the study area do not believe pygmy hippos have any benefits, environmental outreach may positively influence attitudes. Furthermore, the potential for using public citizens in scientific research facilitates exchange of knowledge. For radio telemetry transmitter attachment, I found that a hose-shaped collar was the best and caused minimal abrasion to the pygmy hippo. In the field, I attempted to physically capture pygmy hippos using pitfall traps, and successfully caught a male pygmy hippo in October 2010. However, more time is needed to capture multiple hippos. Camera trapping allowed for estimation of occupancy and activity patterns on Tiwai Island and the surrounding unprotected islands, and also recorded previously undocumented species in the area like the bongo *Tragelaphus eurycerus*. Detection probabilities were low (p < 0.3); however, occupancy appeared to be influenced by habitat type. Pygmy hippos were more likely to occupy riverine and swamp habitats, and had a higher occupancy rate on the smaller surrounding islands. Pygmy hippos were mainly nocturnal; however, they had peaks of activity during the night, and were active later in the morning during rainy season. Camera trapping surveys should expand to further evaluate pygmy hippo populations. With forests continually degraded or lost, a better understanding of the needs of pygmy hippos can better inform range-wide conservation initiatives.

INDEX WORDS: Activity patterns, *Choeropsis liberiensis*, Camera trap, Citizen science, Conservation, Endangered, Environmental attitudes, Human dimensions, Occupancy, Pygmy hippopotamus, Sierra Leone, Technique development

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DEDICATION

This dissertation is dedicated to my parents, Leslie and Joan Conway. Without their support and encouragement through all my adventures in life, none of this would have been possible. I would also like to dedicate this dissertation to those I have lost in Sweet Salone, but who are always in my heart: Kenewa Koroma I, Momoh Magona, and Leslie Kenewa Koroma

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW OF PYGMY HIPPOPOTAMUS

Tropical forests host some of the highest diversity of plant species and endemic vertebrate species globally (Brooks et al. 2002, Norris et al. 2010). However, biodiversity conservation is daunting in these areas due to lack of funding, logistical constraints, lack of understanding of local stakeholder priorities, and political instability (Mittermeier et al. 1998, Hanson et al. 2009). Countries containing these forests have some of the lowest human development indices, where a majority of the population depends directly on natural resources for daily subsistence (Klugman 2011). The Upper Guinea Forests of West Africa, one of the critical or endangered Global 200 ecoregions (Olson and Dinerstein 1998), stretch from Guinea and Sierra Leone and eastwards into western Togo. Encompassing more than 25% of the total vertebrate species on the African continent, these forests were identified as part of the 25 Biodiversity Hotspots because of their high level of endemic species and rapid loss of habitat (Myers et al. 2000). Human-modified landscapes are increasing throughout the region (Gardner et al. 2009). Thus, local input from stakeholders at the onset can help conservation practitioners and land managers as they work to adapt conservation programs to benefit humans, wildlife, and the unique ecosystems in which they reside.

Sierra Leone is located on the western-most extent of the Upper Guinea Forests, and historically contained 1.7 million hectares of moist evergreen and semi-deciduous forests. However, logging, slash-and-burn agriculture, and mining have degraded and fragmented these forests to less than 5% of the original forest cover (Brashares et al. 2004). Most of country is

now a mosaic of agricultural-forest land-uses directly linked to the livelihoods of local people, who depend on these forest fragments for food, medicine, and timber (Norris et al. 2010).

The pygmy hippopotamus *Choeropsis liberiensis* (hereafter pygmy hippo) is an elusive and endangered species endemic to the Upper Guinea Forests of West Africa. Much is unknown about this species, including distribution, use of habitat, home range size, and reproductive biology. However, habitat loss and fragmentation, poaching, and human-wildlife conflict are among the main threats to this species (Mallon et al. 2011). A recently launched "EDGE (Evolutionarily Distinct and Globally Endangered) of Existence Program" by the Zoological Society of London ranked the pygmy hippo as 28 out of 100 mammals that have previously had limited conservation attention, are evolutionarily unique, and are in urgent need of research and conservation action (Isaac et al. 2007). Flagship species are charismatic wildlife that can assist in conservation efforts by creating awareness, enthusiasm, or by symbolizing a specific environmental concern (Walpole and Leader-Williams 2002). Pygmy hippos possess international appeal, cultural value, and charismatic appearance that may allow them to function in this capacity.

In addition to considering human processes in relation to ecosystems, conservation of endangered species depends on knowledge of demographics, abundance, distribution, and habitat use. However, detection of cryptic and rare species creates unique problems due to often solitary and nocturnal behaviors and low population densities over broad areas (Thompson 2004, Ellison and Agrawal 2005). The "Conservation Strategy for the Pygmy Hippopotamus," outlines objectives and proposes actions to assess the current status of the pygmy hippopotamus population range and ensure protection and connectivity of known populations (Mallon et al. 2011).

PYGMY HIPPO ORIGINS AND NATURAL HISTORY

Both the pygmy hippopotamus *Choeropsis liberiensis* and common hippopotamus *Hippopotamus amphibius* are Artiodactyls (even-toed ungulates) originally grouped within the sub-order Suiformes (pigs and peccaries) and associated with the extinct family Anthracotheridae (Oliver 1995). More recently, molecular systematics, morphology and DNA support an ancestral link to cetaceans and hippos have subsequently been grouped into the clade Cetartiodactyla. Research suggests that whales and hippos are sister taxa that branched off 54 mybp (million years before present) (Gatesy 1997, Ursing and Arnason 1998).

The earliest hippopotamids originated during the middle and late Miocene in East Africa and Tunisia (Pickford 1983). However, fossils were also discovered in Asia, the Middle East, and even in Britain (Stuart 1986). Archaeopotamus ("narrow muzzled") is an extinct genus that existed between 7.5 and 1.8 mybp in Africa and the Middle East (Weston 2000) and gave rise to modern day hippos. The genus Hexaprotodon ("six front teeth") which, until recently included the extant pygmy hippopotamus, encompasses most of the 40 species of extinct hippopotamids (Boisserie 2005, Boisserie et al. 2005b). The Cypriot Pygmy Hippopotamus Hexaprotodon *minor* inhabited the island of Cyprus until the early Holocene (Simmons 1999), and 3 species of the Malagasy Hippopotamus existed in Madagascar, but went extinct during the last millennium. These recent species are morphologically similar to the modern day pygmy hippopotamus, and research suggests anthropological factors contributed to their extinction (MacPhee and Burney 1991, Simmons 1999). A distinct subspecies *Hexaprotodon liberiensis heslopi* may exist in Nigeria; however, this population is only known from five specimens and anecdotal evidence, and there have been no confirmed sightings since 1945 (Ritchie 1930, Corbet 1969, Oliver 1995, Blench and Dendo 2007). If the Nigerian population currently exists, it would be 1800 km from

all known pygmy hippo populations and separated by the Dahomey Gap, a dry forest-savanna mosaic in Benin, Togo and Ghana that divides the Upper Guinea Forests from the Congolian Forest Zone (Robinson 1970).

The pygmy hippo looks superficially like the common hippopotamus; however, they differ significantly in both morphology and behavior. A characteristic they both share is a comparable skin physiology that suffers damage when exposed to extended periods of sunlight. With no temperature-regulating sweat glands, hippos have a glandular skin that exudes a shinypigmented fluid, which may protect against sunburn and infection (Olivier 1975, Feldhamer 2007, Hashimoto et al. 2007). Although the two species may share a common ancestor, the genera Hippopotamus and Choeropsis most likely diverged around 8 million years ago, making pygmy hippos the only species in their genus (Boisserie et al. 2005a). Pygmy hippos are notably smaller, weighing between 180 and 275 kg as adults, compared to common hippos at over 1,500 kg. Pygmy hippos are more pig-like in shape (thus their genus name), and have longer legs, a smaller head, and more sloping profile than their larger relatives. Webbed toes allow the feet to splay laterally, which may aid in movement through dense vegetation on land where they may spend much of their time (Eltringham 1999). In fact, pygmy hippos are considered far more terrestrial than common hippos and tend to spend time in wallows, swamps, or in hollows at the base of streams (Robinson 1970).

As non-ruminating foregut fermenters, pygmy hippos are strictly herbivorous, feeding on leaves, ferns, and fruits in the forests, and do not usually forage on grass like the common hippo (Robinson 1970, Eltringham 1993). Like the common hippos, pygmy hippos may affect natural ecosystems at multiple spatial scales by functioning as seed dispersers and nutrient recyclers through spreading of dung (Eltringham 1999, Lewison and Carter 2004). However, unlike the

gregarious common hippo, pygmy hippos are solitary, except for mothers and offspring, which have been reported to spend up to two years together in captivity (Saragusty et al. 2010). In captivity, pygmy hippos have been known to live more than 50 years (Steck and Pagan 2009). They likely do not live as long in the wild.

Although pygmy hippos are endemic to four countries, Côte d'Ivoire, Guinea, Sierra Leone, and Liberia, the majority of the population is thought to occur in Liberia (Lewison and Oliver 2012). Population estimates vary greatly, from 2,000-3,000 throughout their entire range (Eltringham 1993) to a more generous 5,000-10,000 in Taï National Park, Côte d'Ivoire alone (Roth et al. 2004). However, reports agree that the population is declining across the range and is becoming increasingly fragmented (Lewison and Oliver 2012). Out of the estimated 3,000 individuals in the wild, only 80-150 are reported to exist in Sierra Leone (Teleki and Baldwin 1980, Mallon et al. 2011).

The primary threats to pygmy hippos are habitat loss or degradation and poaching. Deforestation through overharvesting of timber, slash-and-burn agriculture, and rapid population growth has become a concern for tropical rainforests (Heywood 1997, Cuaron 2000) which can have repercussions for pygmy hippos who depend on forests for survival. Large-scale logging is a primary reason for loss of old-growth forests and can also lead to increased hunting of rare or threatened mammals (Hall et al. 2003, Lindsell et al. 2011). Poaching for bushmeat is important as a source of protein (de Merode et al. 2004), income (Wilkie and Godoy 2000), and in some cases, a form of crop damage mitigation (Davies and Richards 1991). However, commercial hunting for economic profit rather than subsistence can have detrimental effects on wildlife use, as overhunting can deplete the forests of both vulnerable wildlife and the species that may depend on those hunted species (Redford 1992). The bushmeat trade is cited as one of the

greatest threats to biodiversity (Bennett et al. 2002a, Bennett et al. 2002b, Fa et al. 2002). Species caught for consumption in Sierra Leone are mostly farm-associated species such as cane rat *Thryonomys spp*. and porcupine *Atherurus africanus* (Davies and Brown 2007). However, bushmeat harvesting is a large-scale industry in many countries and an estimated three tons of bushmeat is harvested annually in central African countries (Wilkie and Carpenter 1999). While accounts from range countries have reported pygmy hippo meat in markets, the extent or effect of poaching is still unclear (Mallon et al. 2011).

Conservation of pygmy hippo habitat, including swamps and rivers, also protects the ecosystem services those habitats provide. For example, wetlands that serve as pygmy hippo habitat are important for fiber, building materials, fuel and for cultural aspects of local society (Russell 1965). Furthermore, funds associated with pygmy hippo conservation may stimulate local economic growth, which can promote increased cooperation for conservation initiatives in the area (Gössling 1999, Stronza 2000). Conservation of pygmy hippos relies on a thorough understanding of the effects of anthropogenic influences, as well as an understanding of key habitat requirements and distribution of the species. However, multiple gaps exist in an understanding of how pygmy hippos function in the society and ecosystem.

PYGMY HIPPOPOTAMUS RESEARCH

Research on pygmy hippos has been limited due to recent political instability throughout the region (Lindsell et al. 2011). Furthermore, its semi-aquatic lifestyle, elusive and nocturnal behavior, and rarity make them difficult to study *in situ*. Schomburgk (1912) and Van den Brink (1964) were some of the first non-Africans to observe pygmy hippos in the wild, and used pitfall traps to capture individuals for exportation from Liberia and Côte d'Ivoire. Many of these individuals were destined for European and American zoos and form the foundation for the

current zoological population (Steck 2008). The first in-depth research focusing on pygmy hippos was by Robinson (1970), who described their distribution, explored local hunting methods, and reviewed present and future land uses. In the 1980's, Hentschel (1990) evaluated several capture techniques for pygmy hippos in Côte d'Ivoire including nylon nets, cable snares, run-through traps, and pitfall traps. Nylon nets were eliminated due to high personnel costs, runthrough traps were laborious and logistically challenging, cable snares deemed too high risk for injury, and any safety modifications allowed for escape. After several unsuccessful attempts at capturing pygmy hippos in pitfall traps, Hentschel (1990) enlisted the assistance of Liberian hunters and successfully captured several individuals using pitfall traps in Taï National Park. Eleven animals were transported to Azagny National Park; however, two of the males died and one escaped from the enclosure. Seven translocated pygmy hippos were monitored using radio telemetry for three to six months (Roth et al. 2004); however, one died of unknown causes and another disappeared into a dense swampy area (Bülow 1987). Translocated female home ranges overlapped and were estimated at 40-60 ha, while the male home range of the male covered 150 ha. To date, this has been the only radio telemetry study conducted on pygmy hippos. Hoppe-Dominik et al. (2011) conducted dung counts on transects during 1977–1983 (first study period) and 1995–2004 (second study period) in Taï National Park, Côte d'Ivoire Pygmy hippo dung encounter rates decreased by 33% between the periods, lending support to the hypothesis that pygmy hippo populations are decreasing. Roth et al. (2004) summarized the research conducted in the 1980's and 1990's by Hentschel (1990), Bülow (1987), and Hoppe-Dominik et al. (2011).

Line transects and camera trapping have been used more recently to detect pygmy hippos for abundance estimation throughout their range. The Zoological Society of London (ZSL) conducted a camera trap survey in Sapo National Park, Liberia and obtained seven photographs

of a pygmy hippopotamus (Collen et al. 2011). A three-year bio-monitoring study by Fauna and Flora in in the same area used line transect sampling to detect mammal and avian species (Vogt 2011). A total of 28 pygmy hippo signs, including tracks and dung, were encountered over 13 months of sampling.

Studies are also ongoing in Guinea, Côte d'Ivoire, and Sierra Leone. The ZSL began a camera trapping study in the Loma Mountains of Sierra Leone, and the organization Sylvatrop is currently designing and implementing a long-term pygmy hippo project in Guinea (Mallon et al. 2011). In eastern Sierra Leone and Liberia, the Gola Forest Programme and Across the River Transboundary Peace Park Project have both undertaken recent pygmy hippo research using questionnaires and camera trapping to monitor pygmy hippo conservation status and threats and survey populations (Klop et al. 2008, Hillers and Muana 2011). In Taï National Park, Côte d'Ivoire, several organizations collaborating on a Taï Hippo Project using camera trapping, dung counts, genetic sampling methodology, and footprint analysis.

Conservation research *ex situ* can also provide insight for populations in the field. Taxonomical studies are ongoing to clarify the taxonomy of pygmy hippos with single nucleotide polymorphism (SNP) genetic markers (RZSS and University of Chester *in litt.* 2010). Recent digestive studies have found that pygmy hippos have a generally low food intake, low metabolic rate and long ingest retention times (Clauss et al. 2004, Schwarm et al. 2009). Other studies report surgical procedures, including a caesarean section to remove a dead fetus from an adult female (Flach et al. 1998) and semen collection from male hippos (Saragusty et al. 2010). Pygmy hippos are notoriously difficult to chemically immobilize as they have a historically high mortality rate under anesthesia (Miller 2007). Factors contributing to problems include limited vascular access and proclivity toward hypoxia, bradycardia, hypothermia, ataxia, regurgitation

and cyanosis (West et al. 2008). However, recent research on drug protocols, the most recent by Bouts et al. (2012) which immobilized 14 hippos using a medetomidine-ketamine-isoflurane combination, have significantly improved efficiency and safety. Earlier studies examined the use of various combinations of etorphine, xylazine and azaperone and had varying levels of success (Pearce et al. 1985, Miller 2007).

Reported health issues found in captive pygmy hippos include polycystic kidney disease (Nees et al. 2009), gastroliths (Wings et al. 2008), rectal prolapse (Miller and Boever 1983), bovine tuberculosis (Bouts et al. 2009) and encephalomyocarditis virus (Reddacliff et al. 1997). Haemo *Anaplasma marginale* and ectoparasites (tick) were discovered on one hippo in a Maiduguri Zoological Garden, Nigeria (Mbaya et al. 2008). Other problems found in captive pygmy hippos include dental, skin and foot issues likely related to their husbandry, including monotonous diet without enrichment, lack of access to water sources or low humidity, and all-concrete enclosures and hard flooring (Steck 2008).

SURVEY METHODS FOR RARE AND ENDANGERED SPECIES

Radio telemetry is a common method for locating an animal spatially and temporally and yields information on home range size, habitat use, movement, and demographics by using radio frequencies or a satellite global positioning system (Kenward 2001). Large terrestrial mammals are especially ideal subjects for radio telemetry because they can support larger transmitters with stronger radio signal strengths and battery type. However, species with atypical body shapes and behaviors present challenges for radio transmitter attachment (Walker et al. 2012) because radio telemetry assumes the attachment of a tracking device does not affect the behavior, energy budgets and survival of individuals, which is a particular concern for endangered species (Durnin et al. 2004). While infrequent, studies have demonstrated that external devices may negatively

affect survivorship. For example, collars applied to black rhinoceros *Diceros bicornis* caused abrasions on approximately 15% of collared animals, leading authors to dispute the effectiveness of routine radio-collaring (Alibhai and Jewell 2001) and a study on moose calves *Alces alces* demonstrated calves with ear transmitters had lower survival (Swenson et al. 1999). However, other studies using collars have been conducted on large mammals including Baird's tapirs *Tapirus bairdii* (Hernandez-Divers and Foerster 2001, Noss et al. 2003) and giant pandas *Ailuropoda melanoleuca* with minimal adverse effects (Durnin et al. 2004).

The merits of capturing and handling for research must be balanced against stress to the animal and potential mortality, especially when endangered species are concerned (Osofsky and Hirsch 2000). Various methods have been employed to capture megafauna, including darting (Pienaar 1967), herding into bomas (Morkel and Kennedy-Benson 2011), drop-nets (Barrett et al. 1982), and box traps (Long and Campbell 2012). Pitfall traps, which are excavated and camouflaged holes in the ground, have been used for larger mammal species including Sumatran rhinoceros *Dicerorhinus sumatrensis*, lowland tapirs *Tapirus terrestris* and okapi *Okapia johnstoni* (Lindsey et al. 1999, Emslie et al. 2009, Medici 2010). Traps for Sumatran rhinoceros were approximately 2.5 m in depth and 2.0 m for lowland tapirs (West et al. 2008). These dimensions were also similar to those used by Hentschel (1990) to capture pygmy hippos.

Rare and elusive animals are problematic to survey because of small population size, secretive behaviour, and clumped distribution over broad scales (Thompson 2004). Since researchers are seldom able to detect every individual in a population, several sampling techniques were developed to adjust for imperfect detection, including line transects and presence/absence surveys. Furthermore, technological advances have allowed for more accurate detection of individuals.

Camera trapping is an increasingly popular method for sampling wildlife species, and provides physical evidence of some animals previously undiscovered or thought extinct with minimal disturbance to the animal (Claridge et al. 2005, Pettorelli et al. 2010). Development of commercial game cameras with near infra-red flash, digital storage, motion detection and improved battery life make this method simple to employ and feasible in a variety of environmental conditions (Silveira et al. 2003, Swann et al. 2004). Cameras are cost effective, require minimal labor and training input, and facilitate reliable estimates of occupancy, abundance, species richness, and activity patterns (Kelly 2008, Balme et al. 2009).

A common problem in many studies is the imperfect detection of individuals in a population (Mackenzie 2006). Often entire study areas are too large to be completely surveyed, and few species are so conspicuous that they are always detected. A simple count statistic underestimates the actual abundance, and therefore some measure of detection probability must be incorporated (MacKenzie et al. 2002). Survey methods such as camera trapping can create a detection/nondetection history of a site, which can allow for estimation of occupancy as well as detection probabilities, both of which can vary based on site or survey covariates (MacKenzie et al. 2003). Occupancy models assume that the sampling season is closed, sites are independent, and there is no unexplained heterogeneity in occupancy or detectability (MacKenzie et al. 2005) . Modeling methods are advancing rapidly, and the once basic models that relied on Bernoulli trials (Azuma et al. 1990) have now transformed into maximum likelihood estimation models that include multiple seasons (MacKenzie et al. 2009), multiple species (Dorazio et al. 2006) and abundance estimation (Royle and Nichols 2003).

STUDY AREA

Tiwai Island Wildlife Sanctuary (07°33'N 11°19'W) is part of the Upper Guinea rainforest zone on the Moa River in southeastern Sierra Leone. The Island, adjacent to the western end of the Gola Rainforest National Park, rises to an elevation of approximately 110 m above sea level with an area of 1150.9 hectares or 12 km². Rainfall is approximately 3000 mm per year (Oates et al. 1990). The coastal plains stretch from the south 65 km to the outlet of the Moa River into the Atlantic Ocean. The nearby Kambui Hill Reserves are comprised of two major blocks, North (20 348 ha) and South (880 ha), the southern end reaching within 3 km of Tiwai Island.

Vegetation on Tiwai Island is a mixture of bush fallow, palm swamps, and old secondary forest. Secondary growth from abandoned agricultural fields comprises 30% of the island (Oates et al. 1990) . Tree species in old growth include *Piptadeniastrum africanum*, *Cynometra leonensis*, *Funtunmia africana*, and *Parinari excels* (Fimbel 1994). The surrounding mainland is as a mosaic of upland bush fallow with *Musanga cecropioides*, *Harunqana madagascariensis* and *Sceleria barteri*, secondary forests where coffee and kola nuts are shade-grown, and cassava, groundnut and maize fields. Rice *Oryza glaberrim*, the staple food crop, is grown in both lowland and upland swamps (Richards 2006).

Tiwai Island was first recognized as a valuable ecological area by Dr. John Oates in 1979 and the Island soon became the site of a collaborative research project between Sierra Leone and U.S. universities funded by the U.S. National Science Foundation, the Research Foundation of the City University of New York, the University of Miami, and the New York Zoological Society. Local residents agreed not to hunt on Tiwai during the research, and not to farm areas near the research station (Eichenlaub 1989). In 1984, the local chiefs and residents appealed to

the Forestry Department for Tiwai Island to become a protected area, and in 1987 the island was designated a Wildlife Sanctuary. In 1989, the Tiwai Island Administrative Committee became the governing body for the island, comprised of communities, government agencies, universities and conservation organizations. A management plan was created by a Peace Corps volunteer and provisionally adopted in 1991. Research during this time period focused mainly on the primate community, which is reportedly one of the highest densities of primates in the world with 11 species (Whitesides et al. 1988, Oates et al. 1990, Fimbel 1994, Davies et al. 1999). Tiwai Island also harbors species such as the yellow-backed duiker *Cephalophus silvicultor*, red river hog *Potamochoerus porcus*, and white-breasted guineafowl *Agelastes meleagrides*.

In 1991, a civil war broke out in Sierra Leone, and researchers fled the research station until after 2002 when the war concluded (Gberie 2005). During the war, rebels controlled the Island, destroying the research and visitor station, and local residents report that rebels hunted wildlife on the island for food and profit (M. Conteh, *pers. comm.*), which most likely had a negative impact on wildlife (Lindsell et al. 2011).

The Environmental Foundation for Africa (EFA) took over management of Tiwai Island after the war by acquiring funds for a visitor center and research station from the Critical Ecosystems Partnership Fund. Activities included in the mission were implementation of environmental education in the surrounding villages, maintenance of a visitor camp site and research station, and capacity building with local people to reduce natural resource exploitation (EFA 2004). The original management plan allowed for small-scale farming, mining, and harvesting of forest products (Eichenlaub 1989). However, burning, farming, hunting, logging and mining are currently prohibited on the island.

RESEARCH OBJECTIVES AND CHAPTER OUTLINE

Research objectives were to: 1) estimate occupancy, abundance, and distribution, and describe activity patterns of pygmy hippos relative to Tiwai Island, 2) develop techniques and methodology to study the pygmy hippopotamus *in situ*, and 3) examine interactions and conflicts between pygmy hippos, resource use, and rural people.

This dissertation includes six manuscripts, beginning with an introduction and literature review and concluding with a summary of findings, conservation implications and recommendations for future conservation of the pygmy hippopotamus.

Chapter 2, "Local awareness of and attitudes toward pygmy hippopotamus conservation in the Moa River Island Complex, Sierra Leone" explores the local knowledge on the pygmy hippopotamus from semi-structured surveys and questionnaires administered in 27 villages along the Moa River.

Chapter 3, "A New Context for Citizen Science?: Using Local Knowledge to Inform Wildlife Management and Conservation in Sierra Leone, Africa" explores local knowledge of humanwildlife interactions around a protected area and evaluates the feasibility of a participatory citizen science approach to wildlife research.

Chapter 4, "Evaluation of Radio Transmitter Attachments for the Pygmy Hippopotamus" tests radio transmitter attachments on captive pygmy hippos for subsequent use *in situ*.

Chapter 5, "Physical capture techniques for the pygmy hippopotamus *Choeropsis liberiensis* on Tiwai Island, Sierra Leone" investigates development of techniques to bait, trap, immobile and radio-collar a pygmy hippopotamus in field conditions.

Chapter 6, "Occupancy and activity patterns of the pygmy hippopotamus *Choeropsis liberiensis* on and around Tiwai Island, Sierra Leone" explores the use of camera trapping to obtain

estimates of occupancy and detection probability of the pygmy hippo and describe activity patterns of pygmy hippos.

Chapter 7, "Pygmy Hippopotamus Conservation in Sierra Leone: Summary of Findings and Future Considerations" synthesizes the results of the previous chapters.

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CHAPTER 2

LOCAL AWARENESS OF AND ATTITUDES TOWARD PYGMY HIPPOPOTAMUS CONSERVATION IN THE MOA RIVER ISLAND COMPLEX, SIERRA LEONE¹

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ABSTRACT

The pygmy hippopotamus *Choeropsis liberiensis* is an endangered species that lives only in the Upper Guinea rainforests of West Africa. Using a two phase approach with initial semistructured interviews followed by more extensive questionnaires, we examined local residents' awareness of and attitudes toward the pygmy hippopotamus along the Moa River near Tiwai Island Wildlife Sanctuary in Sierra Leone. Interviews and questionnaires addressed topics including human-hippo interactions, local knowledge and awareness of pygmy hippo ecology and behavior, and public attitudes toward hippo conservation benefits. Overall, 22% of questionnaire respondents acknowledged benefits related to hippo conservation; however, factors affecting perception of pygmy hippos benefits included age, livestock ownership, distance from Tiwai Island and exposure to conservation programs. Results of this study could be used to inform pygmy hippo conservation and illuminate the critical role of local support in endangered species management in global biodiversity hotspots.

INTRODUCTION

Declines in biodiversity precipitated by anthropogenic factors are a major concern in conservation hotspots around the world (Pimm et al. 1995). Human populations, whose survival directly depends on local resources use and consumption, often threaten vulnerable endemic species in these areas (Brockington et al. 2006). In this context, the dynamic relationship between land and people creates a complex management environment where protection of endangered species is inextricably linked to human values and behavior (Hackel 1999). Conservation organizations working in these areas are increasingly challenged to balance biodiversity conservation with human development goals (Brockington et al. 2006). Thus, local input at the onset can help conservation practitioners and land managers as they work to adapt

conservation programs to benefit humans, wildlife, and the unique ecosystems in which they reside. Conversely, limited participation in wildlife management by local communities may lead to negative perceptions of conservation and wildlife (Gillingham and Lee 1999). More research is needed to reveal the importance of a socially-inclusive approach to endangered species conservation (Brewer 2002), particularly those existing near protected areas in Africa (Hartter 2010).

The Upper Guinea Forests are a mosaic of tropical forest in Western Africa identified as a Biodiversity Hotspot (Myers et al. 2000). The pygmy hippopotamus *Choeropsis liberiensis* (hereafter pygmy hippo) is among the most endangered species native to these forests, and current population estimates indicate 2,000-3,000 individuals remain in the wild (Lewison and Oliver 2012). Recently, the Zoological Society of London ranked the pygmy hippo a conservation priority as 28 out of 100 mammals that have received limited conservation attention, are evolutionarily unique, and are in urgent need of conservation action (Isaac et al., 2007). Habitat loss and fragmentation, poaching, and human-wildlife conflicts are considered the major threats contributing to pygmy hippo population declines (Mallon et al. 2011).

Despite the urgent need for pygmy hippo conservation, little is known about these animals, including the specific ecosystem functions they provide. Few people encounter pygmy hippos, and many local residents have only seen one in their lifetime (Eltringham 1999, Hillers and Muana 2011). Studies suggest pygmy hippos are admired for spiritual and aesthetic reasons, and folk stories are often passed orally, demonstrating the role pygmy hippos play in West African culture (Robinson 1996, Hillers and Muana 2011). Like the megaherbivore common hippo, pygmy hippos may affect natural ecosystems at multiple spatial scales by seeking higher quality vegetation (Lewison and Carter 2004) and by functioning as seed dispersers and nutrient

recyclers through spreading of dung (Eltringham 1999). Furthermore, funds associated with pygmy hippo conservation have the potential to stimulate economic growth, promoting cooperation for conservation initiatives in surrounding communities (Gössling 1999).

Human-wildlife conflicts can hinder conservation efforts, especially in developing countries (Gadd 2005). Larger herbivores such as the common hippopotamus (*Hippopotamus amphibious*) and African elephant (*Loxodonta africana*) are among the most problematic due to their ability to cause major crop damage and as a physical threat to humans. For example, Mkanda and Kumchedwa (1997) found farmers in Malawi held negative attitudes towards common hippos because of crop raiding, and respondents in Tanzania believed elephants were dangerous and offered no benefits to local people (Hill 1998). Given the potential for similar conflicts regarding pygmy hippos and their conservation, it is imperative to characterize and account for local perceptions.

To address these research gaps, we investigated the awareness and attitudes of local residents toward pygmy hippos and their conservation in southeastern Sierra Leone. Focusing on villages located adjacent to pygmy hippo habitat around Tiwai Island Wildlife Sanctuary, this study aimed to: (1) assess the nature and extent of human-hippo interactions, including local knowledge of pygmy hippo ecology and behavior, and (2); characterize public attitudes toward hippo-related benefits and identify demographic and contextual factors influencing perceived benefits.

STUDY AREA AND CONTEXT

Tiwai Island (07°33'N 11°19'W) is a 12 km² island on the Moa River adjacent to the Gola Rainforest National Park (Fig. 2.1). The Island is composed of bush fallow, palm swamps, and secondary forest (Dasilva 1992). Near Tiwai Island, the river splits into channels due to

geographic faulting, resulting in hundreds of islands (Eichenlaub 1989). The surrounding mainland is a mosaic of secondary forests, upland bush fallow, lowland swamps, and cultivated fields.

Tiwai Island was designated a Wildlife Sanctuary in 1987 and is jointly owned by eight host communities in Barri and Koya Chiefdoms who share annual tourism revenues associated with activities on Tiwai Island (Oates 1999). After a decade long civil war ended in 2002, the Environmental Foundation for Africa (EFA) established management of Tiwai Island by funding a visitor center and research station and initiated several outreach programs targeting the eight communities (EFA 2011).

Residents in this region are primarily farmers who rely heavily on subsistence rice farming, but also derive supplementary income from palm oil, cocoa, and kola nut cash crops (Leach 1994). Fish is a major component of the diet, but bush meat is also an important protein source (Davies and Richards 1991).

METHODS

Our study involved two phases during a two-year time span: semi-structured interviews and questionnaires. Following a pilot test in Kambama village in early January 2009, semistructured interviews were conducted in the eight host villages (January – June 2009). In the first phase, we interviewed 33 people using a snowball sampling approach, which allowed respondents to recruit future subjects and was useful for a sampling frame that was difficult to establish (Biernacki and Waldorf 1981). Interviews were conducted by the lead researcher and a local research assistant who translated questions into the Mende language. Conversations occurred in private homes during the early morning and late evening when most people were home from farming, and typically lasted 20-40 minutes. Interviews focused on people who were

at least moderately familiar with pygmy hippos (two to nine participants per village, Table 2.1) and were open-ended, focusing on number and location of pygmy hippo encounters, local knowledge of pygmy hippo ecology, and perceived benefits associated with Tiwai Island and pygmy hippos (Appendix 1). Basic demographic information was recorded for interview participants. Interviews were used to identify key concepts that informed development of the broader phase two questionnaire.

Following interviews, an outreach program was delivered in the eight host communities during January to April 2009. The program was a complement to the Environmental Foundation for Africa's environmental education programs. During these visits, we conducted a presentation that outlined preliminary results of ongoing pygmy hippo research with the objective of raising awareness of threatened species in the area. Subsequent discussions allowed villagers to ask questions about the research program and pygmy hippo conservation.

Phase two of the study, which occurred the following year, involved a questionnaire across a broader geographic area that extended 32 km from Tiwai Island. Villages along the Moa River farther than 32 km did not report pygmy hippo presence and logistical constraints made further exploration unsuitable. During this phase, we selected 27 villages, including the original Tiwai-proximal communities, to participate in in-person intercept surveys using questionnaires. Targeted villages were based on a reconnaissance survey that ranked villages by willingness to participate and logistical suitability. Respondents were chosen opportunistically as the research team moved through the village, whether or not they were familiar with pygmy hippos. Villages closer to Tiwai Island were visited from late August to early October 2010 and villages more than 10 km away were visited from late October to December 2010. Questions about pygmy hippo encounters, crop damage, and bushmeat consumption included both dichotomous and

open-ended items (Appendix 1). Respondents were allowed to give multiple answers to questions about pygmy hippo benefits. Items assessing attitudes towards pygmy hippos and hippo conservation were measured on a three-point scale where -1 = "disagree," 0 = "unsure," and "1" = agree. Demographic characteristics recorded included age, gender, education level, and resident status.

The overall phase two questionnaire sample included 522 respondents. Participation rates were comparable across all sites (ranging from 12-30 participants per village), with approximately 5% of the estimated population chosen to obtain adequate representation for statistical inferences (Vaske 2008). Due to a lack of official census data, village authorities were asked to provide an estimation of village population. Questionnaires were conducted in Mende by three local residents trained in the administration process; each administrator collected approximately one-third of the questionnaires.

Data Analyses

Semi-structured interview responses were not statistically analyzed beyond descriptive frequency results due to their small sample size and qualitative nature. However, basic descriptive information, including demographics, hippo sighting occurrence, and general themes of hippo-human interactions that emerged were used to inform phase two questionnaire design.

Questionnaire data from phase two were analyzed using SPSS *v. 19.0* (Statistical Package for the Social Sciences, SPSS Inc., Chicago, IL USA). Using χ^2 tests of independence, differences among individuals in the 27 villages were examined based on their demographic characteristics. We developed a binary logistic regression model to evaluate the relative influence of multiple predictors, including demographic variables, distance from Tiwai Island, and exposure to conservation education programs on respondents' recognition of benefits

associated with pygmy hippo conservation around Tiwai Island. The outcome variable was a discrete choice between two response options: participants either recognized benefits associated with pygmy hippos (n = 112) or expressed uncertainty or skepticism regarding hippo-related benefits (n = 406). Cases with missing values on at least one item for the predictors of interest (3.8%) were excluded from the analysis. The question "pygmy hippos damage crops" was asked using two different methods for cross-validation purposes. Odds ratios were used to compare the probabilities of the respondent's perceptions based on demographic factors.

RESULTS

Demographic Overview

Semi-structured interviews in phase one were primarily conducted with males (94%); when females were approached (n = 8), some were reluctant to speak, stating they knew nothing of the topic or were unavailable. Mean age was 41.8 (\pm 13.5). Questionnaire respondents in phase two were more evenly distributed between genders and mean age was 44.8 (\pm 16.4). Education levels were generally low; only 10.1% of participants had any experience with secondary schooling. Most respondents owned livestock including sheep, goats and chickens. Mean household size was 7.60 (\pm 4.37). Demographic ratios within the sample did not differ significantly as distance from Tiwai Island increased and, based on anecdotal evidence from the area, sample characteristics seemed to accurately reflect the population throughout the region. *Pygmy Hippo Ecology & Human-Hippo Interactions*

All semi-structured interviews participants reported seeing ≥ 1 pygmy hippo in their lifetime, although one participant observed only a dead hippo. Few (27.2%) had seen a pygmy hippo within the previous year, and two had not seen a hippo since the civil war ended in 2002. Of the most current encounters, most (68.8%) occurred on the mainland, with only 6.3% of the

observations on Tiwai Island and 15.6% of observations on the smaller islands south of Tiwai Island. Three respondents (9.4%) could not recall where they had seen the hippos.

During questionnaire implementation, 35.1% of respondents claimed to have seen ≥ 1 pygmy hippo since the previous rainy season in May 2009 with a mean of 2 (± 1.3) hippo sighting per individual. In general, sightings were more commonly reported by respondents within 2.0 km of Tiwai Island (49.4%) compared to respondents (25.5%) who were more than 15 km away ($\chi^2 = 3.4$, df = 1, p = 0.06; Fig. 2.2). However, distance from the Moa River had no significant influence on pygmy hippo sightings. Gender was the only significant demographic variable, with males more likely than females to have seen a pygmy hippo since the last rainy season ($\chi^2 = 30.8$, df = 1, p < 0.001).

Semi-structured interview participants provided insight into pygmy hippo foraging behavior. The majority of participants (93.9%) believed pygmy hippos consume crops. Several participants stated that although the pygmy hippo did not often eat crops, pygmy hippo movements through a field in search of okra or sweet potato damaged their rice. When asked whether it was possible to prevent a pygmy hippo from entering the farm, six participants believed building a fence could help, although several believe pygmy hippos could break most fences.

While the majority of semi-structured interview participants reported that pygmy hippos consume crops, only 27.8% of the questionnaire respondents believed pygmy hippos cause crop damage and 7.3% were unsure. Ten people believed pygmy hippos were the most destructive crop pest, far behind cane rats *Thryonomys swinderianus* and red river hogs *Potamochoerus porcus*. Reports of hippo-related crop damage differed significantly as village distance from Tiwai Island increased, with hippo crop damage reported more often among villagers farther

from Tiwai Island ($\chi^2 = 8.5$, df = 2, p = 0.01). However, reported hippo crop damage decreased significantly as distance increased from the Moa River ($\chi^2 = 22.5$, df = 6, p < 0.01). Males were significantly more likely to report hippo-related crop damage than females ($\chi^2 = 9.8$, df = 2, p = 0.007).

When semi-structured interview participants were asked about hippo meat consumption, 14 people (42%) responded they had tried pygmy hippo meat \geq 1 time in their lifetime, and participants repeatedly acknowledged the sweetness, or deliciousness, of pygmy hippo meat. However, of 518 questionnaire respondents who answered the question, "Which wild meat do people catch most often in traps?" pygmy hippo was not reported. In fact, only two villagers listed pygmy hippos as a preferred source of meat.

Local Perceptions of Pygmy Hippo Conservation Benefits

Many semi-structured interview participants (69.7%) believed pygmy hippos offered benefits, including attracting researchers and visitors to the area (30.3%). Four participants responded pygmy hippos were valuable for aesthetic purposes as they were very "fine" and exhibited characteristics, such as smooth skin and neck rolls, similar to human babies and beautiful women. Another participant believed pygmy hippos were "lucky animals," and two farmers believed pygmy hippo presence alone could deter agricultural pests such as the cane rat. Several participants were unsure of direct benefits, but one stated, "[Pygmy hippos] bring many people like the BBC. If pygmy hippos have no benefit, why would people come from London to search for it?" Three participants mentioned pygmy hippo feces could be used as fertilizer for their gardens. However, 21.2% of participants felt meat was the primary benefit hippos provided; "I never get benefit from the pygmy hippo unless…we kill it." Overall, only 21.6% of questionnaire respondents recognized benefits to local communities and 9.1% were unsure. In villages near Tiwai Island (n= 368), the most commonly cited benefits were attracting researchers and bringing other visitors such as tourists to the area (Fig. 2.3). Farther from Tiwai Island, the only respondent who recognized any benefit from hippos valued only the meat. The most common reasons explaining why pygmy hippos were not beneficial included their relative inutility, the potential danger they pose, and the damage caused to crops.

The logistic regression model supported the existence of a relationship between the predictor and some outcome variables (Nagelkerke $r^2 = 0.50$) and revealed the relative influence of multiple predictors on respondents' recognition of pygmy-hippo related benefits (Table 2.2). Furthermore, the classification accuracy rate based on the model (86.3 %) was higher than the proportional by chance accuracy rate. Parameter estimates (β) and odds ratios showed the distance of respondent from Tiwai Island and exposure to conservation education were the strongest predictor variables of hippo-related benefit awareness. Respondents in villages far from Tiwai Island were less likely to recognize benefits associated with hippo conservation than respondents who lived closer ($\beta = -0.89$, df = 1, p < 0.001; Fig. 2.4). Respondents in villages exposed to conservation education programs were over ten times more likely to recognize benefits associated with hippo conservation ($\beta = 2.36$, df = 1, p < 0.001). For example, 65.3% of respondents from villages where outreach efforts occurred both by the Environmental Foundation for Africa and the research team thought pygmy hippos were beneficial to local communities compared to 7.9% of respondents in other villages ($\chi^2 = 183.7$, df = 1, p < 0.001). Older residents were 1.3 times more likely ($\beta = 0.23$, df = 1, p = 0.04) and livestock owners were

twice as likely ($\beta = 0.83$, df = 1, p = 0.04) to recognize benefits associated with pygmy hippo conservation.

DISCUSSION

Pygmy Hippo Ecology & Human-Hippo Interactions

Results suggest local residents represent an important source of information regarding pygmy hippo ecology and behavior. The frequency of pygmy hippo sightings was inversely related to the distance of respondents from Tiwai Island, which may be due to the highly vascular skin of pygmy hippos that is prone to dehydration, making them dependent on water availability (Eltringham 1999). The primary water source near Tiwai Island is the Moa River, and pygmy hippos use many of the smaller islands as refuge (A. Conway, unpublished data). Therefore, pygmy hippos may be more abundant in villages closer to the river, resulting in more frequent sightings. Furthermore, more male respondents generally encountered pygmy hippos than females, which may be influenced by societal activities; men spend more time on the river fishing at peak pygmy hippo activity hours (e.g., dawn and dusk), whereas women fish in social groups in streams and swamps during mid-day hours (Leach 1994).

Although hippos were not viewed as crop pests by local residents in this study or by a similar study by Hillers and Muana (2011), the affinity of pygmy hippos for vegetation in agricultural fields has the potential to result in human-wildlife conflicts (Mallon et al. 2011). Pygmy hippo crop damage appeared to be most prevalent closer to the Moa River, mirroring studies of the common hippopotamus reporting that farms near the river and hippo access points were more likely to be raided (Kendall 2011). Suspected crop damage is often associated with negative attitudes toward hippos. For example, farmers in Malawi held negative attitudes towards common hippos and were especially intolerant of crop grazing, and 600 hippos were

killed or wounded within 4 years (Mkanda and Kumchedwa 1997). However, lethal control was not an effective preventative method for common hippos (Mkanda 1994). Due to the endangered status of pygmy hippos, this is an even less desirable solution in Sierra Leone. However, as forests and swamps are converted to farmland and pygmy hippo habitat decreases, human-hippo conflicts may also intensify (Norris et al. 2010).

Wild-caught meat is important to daily life in Sierra Leone as a source of income, a method of reducing crop damage, and a valuable protein source (Davies and Brown 2007). Koster et al. (2010) found hunters target animals with rich flavor, high fat content and large body mass – characteristics that would predispose pygmy hippos to hunting pressure. Although few respondents claimed to have eaten pygmy hippo meat, all those who had agreed the meat was delicious. Furthermore, our surveys may have underestimated the intensity of pygmy hippo hunting, as respondents may have been hesitant to reveal illegal activities. However, during our preliminary visits to villages, three of the 27 villages reported recent hippo hunting. The Wildlife Conservation Law of 1972 prohibits hunting of endangered species, but does not offer adequate support for implementation and enforcement (USAID 2007). While accounts from range countries have reported pygmy hippo meat in markets, the extent of poaching is still unclear (Mallon et al. 2011). Therefore, hunting of hippos across all range countries should continue to be monitored.

Local Perceptions of Pygmy Hippo Conservation Benefits

Most study participants, and particularly those living farther from Tiwai Island, did not recognize benefits associated with pygmy hippos. This finding clearly represents a major barrier to pygmy hippo conservation efforts. When residents do not place a positive value on wildlife, perceptions of negative interactions such as crop damage can be exaggerated (Gillingham and

Lee 2003). Our results found that respondents farther away from Tiwai Island were also more likely to report hippos as crop pests, which could be a reflection of negative attitudes. Nevertheless, we identified certain factors that might increase the likelihood for local support. Livestock owners were generally more positive and were twice as likely to perceive benefits associated with pygmy hippos. Gadd (2005) reported similar results in a study of elephants in Kenya, noting pastoralists were more tolerant of large herbivores than pure agriculturalists. In the Tiwai area, livestock owners generally enjoy improved livelihoods because of supplemental income, and this could influence tolerance towards wildlife such as hippos (Davies and Richards 1991, Randolph et al. 2007).

Older residents were more likely to recognize hippo-related benefits, perhaps because they remember the era before the civil war when foreign researchers were heavily involved and they experienced a positive association between conservation and foreign investment. These differences highlight the effects that changes in political stability over time have on ecotourism and wildlife conservation in the country. For example, nearly twice as many tourists visited Sierra Leone in 1986 compared to 2009 (Shakya 2009). With fewer visitors reaching Tiwai Island, the younger generation has not experienced the economic benefits of conservation. However, anecdotal evidence suggests recent tourists are attracted by the possibility of finding pygmy hippos, and guidebooks promote the island as a valuable refuge for endangered species (Manson and Knight 2012).

Ecotourism has been shown to positively impact the attitudes of local people towards conservation in countries like India (Sekhar 2003) and Kenya (Gadd 2005). These impacts are often enhanced through concerted efforts to focus on umbrella species of ecological and socio-economic significance (Walpole and Leader-Williams 2002). Pygmy hippos possess

international appeal, cultural value, and charismatic appearance that would allow them to function in this capacity, but Sierra Leone's current infrastructural limitations represent a major barrier to ecotourism. For instance, annual returns from research and tourism at Tiwai Island are approximately \$4000US, barely covering basic maintenance costs (EFA 2011). Though opportunity for improvement exists, research in other areas suggests that people may revert to previous consumptive behaviors when potential economic gains are not realized (Pretty and Smith 2004). Reports by community members also indicate poaching and diamond mining on Tiwai Island is increasing. With little enforcement, and conservation revenues minimal, these activities may escalate and continue to threaten the sustainability of Tiwai Island as a protected area.

Results of our study suggest conservation education programs by the Environmental Foundation for Africa and our team generated support for pygmy hippo conservation around Tiwai Island. Formal education is uncommon in the study area and, when it does occur, little attention is given to the content of environmental education topics (Skuce 2002). Alternative delivery mechanisms should therefore be considered, particularly those with a core message that resonates with local stakeholders such as an ecosystems benefits approach (Mertz et al. 2007). Furthermore, because pygmy hippo habitat extends well beyond the boundaries of Tiwai Island, support for hippo conservation efforts from stakeholders outside the sanctuary is critical. Pygmy hippos would likely benefit from a collaborative initiative by conservation and governmental organizations in Sierra Leone to expand management objectives and outreach efforts farther away from protected areas integrating socio-cultural considerations and human dimensions research into landscape level conservation practices (Mallon et al. 2011).

Implications

Results from this study are currently being disseminated to stakeholders in Sierra Leone and across pygmy hippo range countries via newsletters, peer-reviewed articles and conferences. The Environmental Foundation for Africa recently received funding for environmental education outreach targeting pygmy hippos in the Tiwai Island area, and a number of ongoing research and education-oriented programs in other range countries are also contributing the growing knowledge base (e.g. Gola Forest Programme in Sierra Leone, the Zoological Society for London and Fauna & Flora International in Liberia, Sylvatrop in Guinea and IBREAM in Côte d'Ivoire). A meeting for the creation of the IUCN Conservation Strategy for the Pygmy Hippopotamus in 2010 assembled stakeholders, conservation organizations, researchers, and government officials to determine threats and conservation actions for pygmy hippos (Mallon et al. 2011). Future research should continue to explore the dynamic ways local input and support can contribute to species management in biodiversity hotspots around the world.

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Table 2.1. Demographic characteristics of semi-structured interview participants (January-June, 2009, n = 33) questionnaire respondents (August-December, 2010, n = 522) in villages around the Tiwai Island Wildlife Sanctuary, Sierra Leone (Fig. 2.1).

Variable	Semi-Structured Interview (%)	Questionnaire (%)
Gender		
Female	6.1	43.6
Male	93.9	56.4
Age		
18-29	18.8	13.4
30-39	25.0	29.2
40-49	31.3	24.4
50-59	3.1	11.5
60+	21.9	21.5
Occupation		
Farmer	69.7	89.8
Tiwai Staff	12.1	0.0
Fishermen	9.1	0.4
Miner	3.0	0.6
Merchants	0	4.2
Other	3.0	4.4
Education		
None	-	41.7
Arabic/Primary	-	48.2
Secondary	-	10.1
Resident Status ^a		
Native	87.9	88.4
Immigrant	12.1	11.6
Distance from Tiwai		
0 - 2.0 km	63.6	14.8
2.01- 5.0 km	24.2	42.3
5.01-15.0 km	12.1	23.4
> 15.01 km	0	19.5

^aPeople born in the surveyed village or in a tributary village were defined as native; an

immigrant was defined as somebody born outside these villages (Davies and Richards 1991).

Table 2.2. Parameter estimates and odds ratios in the binary logistic regression model predicting questionnaire respondents' (n = 518) awareness or lack of awareness of pygmy hippo-related benefits near Tiwai Island Wildlife Sanctuary, Sierra Leone

Variable	B ^a	SE	Wald	Odds	Predicted
vallable				Ratio ^b	Probability
Constant	-1.55*	0.80	3.78		
Gender (male)	0.23	0.33	0.45	1.25	0.56
Age	0.23*	0.11	4.21	1.26	0.56
Household Size	-0.05	0.03	2.21	0.95	0.49
Resident Status (native)	0.10	0.46	0.04	1.10	0.52
School (some education)	0.10	0.34	0.09	1.11	0.53
Occupation (farmer)	-0.79	0.46	2.93	0.45	0.31
Livestock Ownership	0.83*	0.42	3.95	2.28	0.70
Distance from Tiwai	-0.89**	0.19	21.32	0.41	0.29
Conservation Education	2.36**	0.33	51.44	10.57	0.91

^a*p < 0.05, **p < 0.01, ***p < 0.001.

^bA measure of association between the dependent variable and each independent variable.

Cox & Snell $r^2 = 0.32$; Nagelkerke $r^2 = 0.50$

Preliminary tests for multicollinearity among predictor variables indicated that intercorrelation levels were appropriate for analysis (Tolerance ≥ 0.71 , VIF ≤ 1.46). Full Model, $\chi^2 = 201.1$, df = 9, p < 0.001. A non-significant Hosmer and Lemeshow goodness-of-fit test suggested that the observed and predicted group assignments did not differ, $\chi^2 = 5.8$, df = 8, p = 0.70.



Figure 2.1. Map of Tiwai Island, Sierra Leone, showing communities along the Moa River where interviews (host communities) and questionnaires (host communities plus other communities) occurred from January 2009 – December 2010). Inset displays the location of Tiwai Island within Sierra Leone.



Figure 2.2. Percentage of questionnaire respondents (n= 522) reporting pygmy hippopotamus *Choeropsis liberiensis* sightings since the last rainy season (September 2009) in villages surrounding Tiwai Island Wildlife Sanctuary (August – December 2010). Error bars indicate standard errors.


Figure 2.3. Percentage of questionnaire respondents (n=518) in 27 villages surrounding Tiwai Island Wildlife Sanctuary, Sierra Leone with positive or negative perceptions associated with pygmy hippopotamus *Choeropsis liberiensis* conservation (August – December 2010).



Figure 2.4. Percentage of questionnaire respondents (n = 518) in 27 villages with positive or negative perceptions toward pygmy hippopotamus *Choeropsis liberiensis* in relation to distance from Tiwai Island Wildlife Sanctuary, Sierra Leone (August – December 2010).

CHAPTER 3

A NEW CONTEXT FOR CITIZEN SCIENCE?: USING LOCAL KNOWLEDGE TO INFORM WILDLIFE MANAGEMENT AND CONSERVATION IN SIERRA LEONE, AFRICA¹

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ABSTRACT

Global declines in biodiversity caused by anthropogenic factors are a major concern in conservation hotspots. Indigenous knowledge of rural villagers can inform conservation efforts by providing an understanding of human-wildlife interactions and ecological information on little known species. To explore crop depredation and bushmeat consumption, questionnaires were administered to 522 people in 27 villages near Tiwai Island Wildlife Sanctuary, Sierra Leone. These questionnaires were followed by semi-structured interviews to assess the feasibility of public participation in scientific research (PPSR). According to study participants, cane rat Thryonomys swinderianus and red river hog Potamochoerus porcus caused the most crop damage. Wild-caught meat appeared to be an important food source, with squirrel and cane rat listed as common species consumed. Semi-structured interview respondents discussed community contributions to science, challenges in working with foreign researchers and motivations for public participation in science. The desire for compensation was a theme that repeatedly emerged in discussions. Public participation in science may be complex in these dynamic landscapes; however, involving local people can improve public understanding of ecological processes while fostering environmental stewardship.

INTRODUCTION

The Upper Guinea Rainforests of West Africa are among the 25 global biodiversity hotspots identified as a conservation priority due to high levels of endemism and threatened species (Myers et al. 2000). These tropical forests support approximately 25% of all African mammals; however, less than 5% of the Upper Guinea rainforests are formally protected and most remaining tracts persist as fragments surrounded by a matrix of human-modified landscapes (Norris et al. 2010). Anthropogenic impacts on these forested ecosystems are significant, for

these forests exist primarily in countries with low human development indices where a majority of the population depend directly on natural resources for daily subsistence (Klugman 2011). In this respect, the Upper Guinea rainforests of West Africa face a dilemma similar to many threatened tropical ecoregions. Creative solutions acknowledging and supporting human livelihoods while contributing to conservation and natural resource management in these biodiversity hotspots are therefore urgently needed (Cincotta et al. 2000). This study explored how one potential solution, public participation in scientific research (PPSR), could help researchers and local communities work to collectively accomplish both goals.

Importance of Human Wildlife-Interactions

In many developing countries, interactions between humans and wildlife substantially influence both local livelihoods and conservation efforts in various ways. For example, conflicts with wildlife can exact considerable costs on local people through destruction of crops (Hill 2000), attacks on livestock (Michalski et al. 2006), and transmission of zoonoses (Wastling et al. 1999). Crop destruction by wildlife, in particular, can inflict significant costs on humans through loss of income and lost time spent trying to prevent raiding events (Weladji and Tchamba 2003). For instance, Mkanda and Kumchedwa (1997) estimated a 22% loss of the monetary value of maize and rice crops in a village in Malawi due to common hippopotamus *Hippopotamus amphibious*. In fact, conflict related to crop raiding is one of the primary motivations for retaliation killings of wildlife, as in the case of the common hippopotamus (Kendall 2011). Retaliation killing becomes a larger problem when it involves endangered species such as Asian elephants (Hedges et al. 2005). Negative experiences such as these are a key factor affecting attitudes towards wildlife and often limit local acceptance of conservation initiatives (Tessema et al. 2010).

Although some human-wildlife interactions, like hunting, can benefit humans, overharvest is an increasing concern. Bushmeat (or wild-caught meat) is important as a source of protein in many developing countries (de Merode et al. 2004). Bushmeat harvesting is also important as a source of income in West and Central Africa (Wilkie and Godoy 2000), and, in some cases, a method of crop damage mitigation (Davies and Richards 1991). However, increasing human populations and escalating hunting pressure may have dire consequences for people and ecosystems in areas where bushmeat harvesting is often a way of life. In fact, the use of bushmeat for subsistence and commercial purposes is often cited as one of the greatest global threats to biodiversity (Milner-Gulland and Bennett 2003) and is particularly problematic on the African continent (Noss 1998a, Barnes 2002). Furthermore, studies in Central Africa indicated even common duiker species are hunted to unsustainable levels (Noss 1998b), which may also reflect the decline in West African wildlife populations (Barnes 2002).

Although human-wildlife interactions are often negatively viewed as sources of conflict, positive relationships between human and wildlife producing ecological, social, or economic benefits for local people (e.g., ecotourism, community-based initiatives) also exist. Studies suggest these positive human-wildlife interactions can increase support for conservation (Stem et al. 2003, Mazur and Stakhanov 2008). The challenges of understanding and managing human-wildlife interactions are especially evident in and around protected areas (PAs), which represent focal points for conservation efforts in many developing countries. Here, boundaries between natural habitat and human-dominated landscapes are poorly defined and resource utilization and preservation-oriented priorities often collide (Weladji and Tchamba 2003). Although research is beginning to illuminate the extent and the effects of human-wildlife interactions in PAs around the world, they are often constrained by inadequate funding, limited staff, and inaccessible

landscapes (many of these PAs are in remote regions). Regardless, these studies typically overlook an underutilized resource. Local people who inhabit these regions often have an intimate knowledge of local tropical ecosystems and the flora and fauna contained therein. By soliciting input from and collecting data generated by local residents, researchers could expand their potential for knowledge production in these challenging study systems.

Using PPSR to Characterize Human-Wildlife Interactions

One method that holds promise for integrating scientific research and local knowledge is the use of public participation in scientific research (PPSR), also sometimes referred to as citizen science (Bonney et al. 2009b). Citizen science exists in a variety of forms and is used as both a research strategy and an informal science education tool. In addition to generating valuable data to address important research questions, citizen science projects are also designed to increase public awareness, knowledge, and understanding of a particular topic or issue, to enhance engagement and interest, to build skills, and to influence attitudes and behaviors (Bonney et al. 2009b). Citizen scientist and PPSR monitoring are becoming popular strategies for assessing large-scale ecological trends (Silvertown 2009, Dickinson et al. 2010), particularly in industrialized countries like the United States (Lepczyk 2005) and Canada (Sharpe and Conrad 2006); however, this approach is less established in developing countries.

Because citizen science participation often requires participants to contribute substantial resources of their own (especially computers and Internet access), most PPSR projects often exclude rural, impoverished regions where technological and economic resources are scarce (Braschler 2009). Instead, citizen science-style work in these low income regions is often depicted within "ethnoscience" or "indigenous knowledge" (IK) frameworks (Leach and Fairhead 2002). In addition to improving scientific understanding of ecological phenomena, local

engagement, adds a social and cultural element, which may increase support for and sustainability of community-based conservation efforts (Gadgil et al. 1993, Berkes et al. 1995).

Despite these benefits, IK and traditional science have had a discordant past, with a history of top-down approaches operating under the assumption that outside experts could diagnose problems and implement programs without input from local populations (Sillitoe 2000, Aikenhead and Ogawa 2007). In fact, Leach & Faircloth point out the "lack of commensurability between rural people's concepts and those employed by modern science" (p. 301). To bridge this gap, IK is increasingly recognized a critical component of sustainable development and conservation goals (Agrawal 1995, Snively and Corsiglia 2001). The integration of local knowledge into scientific research and conservation planning reflects this change (Smith 1999, Berkes et al. 2000), and local input from non-scientists is now used for a variety of purposes including the design of marine reserves (Drew 2005) and the development land protection priorities based on the use of ethnobotany and recognition of sacred cultural sites (Lebbie and Guries 1995).

Despite this progress, effective integration of IK and conventional science-based conservation efforts in developing countries remains a major challenge. The expansion and adaptation of western PPSR models (i.e., those currently employed in Europe in North America) could help to address this problem. Because biodiversity hotspots such as the Upper Guinea rainforests contain some of the most diverse yet poorly understood ecological assemblages on the planet, research and monitoring strategies that capitalizes on local residents' knowledge in these settings (including interactions with local wildlife) may prove to be invaluable (Folke 2004). To realize this potential, scientists should begin to understand the forces motivating local residents to actively engage in research studies, as well as the factors constraining their

participation. Innovations such as CyberTracker, a program that allows illiterate trackers to record animal sign for monitoring, have created novel opportunities for rural people to contribute to ecological research (Liebenberg et al. 1999), but additional room for growth remains. As global conservation programs simultaneously work to advance scientific knowledge and enhance connections between local people and local resources, citizen science might have an important role to play.

In this study, we explored the potential value of a PPSR-style project in a biodiversity hotspot: the Upper Guinea rainforests of southeastern Sierra Leone. The study involved rural villagers living near a protected area (Tiwai Island Wildlife Sanctuary) along the Moa River. We were interested in both ecological and social-psychological questions. Specifically, our objectives were to: (1) utilize local knowledge to characterize the nature and extent of human-wildlife interactions in the region around the protected area, focusing on crop depredation and bushmeat harvesting, and (2) evaluate the feasibility of a PPSR approach to conservation research by examining local attitudes toward the process and exploring the potential benefits and challenges of citizen science within the study context.

STUDY CONTEXT

Tiwai Island Wildlife Sanctuary (07°33'N 11°19'W) is a 12 km² island on the Moa River in southeastern Sierra Leone at the western end of the Gola Forest National Park systems (Figure 3.1). Designated as a Wildlife Sanctuary in 1987, the Island is owned by eight host communities in Barri and Koya chiefdoms who share a portion of annual profits from tourism and research (EFA 2011). Secondary growth from agricultural fields makes up 30% of Tiwai Island, with palm swamp and secondary forest contributing to the remaining land area (Oates et al. 1990). The original management plan for Tiwai Island allowed for small-scale farming, diamond

mining, and harvesting of some non-timber forest products (Eichenlaub 1989). However, these activities are prohibited under the current management plan, with cooperation from the local residents (EFA 2004). The land surrounding Tiwai Island is a mosaic of upland bush fallow, secondary forests, lowland swamps and agricultural fields. Southeastern Sierra Leone is predominantly populations of Mende ethnicity who are subsistence rice farmers (Leach 1994). Residents near Tiwai Island derive supplementary income from small-scale palm oil, cocoa, peanut and kola nut cash crops (Davies and Richards 1991).

The PPSR study was a segment of a broader study on the ecology and conservation of the pygmy hippopotamus *Choeropsis liberiensis* (hereafter pygmy hippo), an endangered species endemic to the Upper Guinea Rainforest of West Africa. Camera trap surveys and radio telemetry method development occurred on and around the Tiwai Island Wildlife Sanctuary from 2008-2011. The Tiwai Island Wildlife Sanctuary is an important refuge for many species, but it is a particular stronghold for the pygmy hippo. With their unique charismatic appeal, pygmy hippos could serve as a flagship conservation species for the region. However, urgent anthropogenic threats to pygmy hippo survival include poaching and deforestation from agricultural use and logging (Mallon et al. 2011). In general, basic ecological details about pygmy hippos are lacking due to their cryptic, solitary lifestyles and nocturnal behavior, rendering research, conservation and management difficult. Therefore, integration of local knowledge of human-wildlife interactions, especially those involving pygmy hippos, could become a vital component of efforts to conserve the Upper Guinea Rainforest.

METHODS

We used a "contributory project" PPSR model where the study and corresponding research questions were designed by the lead scientists, with members of the public (i.e., local

villagers) serving as the primary data contributors (Shirk et al. 2012). Following a series of informal meetings and conversations with local villagers in 2009 to prepare residents for the upcoming research effort, data collection occurred via intercept survey in 27 villages along the Moa River from August to December 2010. We chose villages based on their willingness to participate, which was determined by a focus group in each village before the survey began. Researchers asked village elders and chiefs preliminary questions about pygmy hippo presence near their village. They were also asked whether they would be willing to participate in a survey in the future. Furthermore, villages more than 5 km from a road were excluded due to logistical constraints. Villages farther than 5 km from the river were also excluded. Thirty-one villages were visited, 27 met the criteria, and all were located within 32 km of the Tiwai Island Wildlife Sanctuary. Trained research assistants who spoke the Mende language visited villages to collect data, traveling on foot and visiting 1-2 villages per day for 24 survey days. Assistants conducted surveys in the early morning or evening when most people were home from their fields. Respondents (n = 522) were chosen opportunistically as the assistants moved through the village with approximately five percent of the estimated population surveyed for sufficient representation (Vaske 2008). Participation rates ranged from 12 - 30 people per village.

To address the first research objective, the survey focused on human-wildlife interactions including crop depredation and bushmeat consumption. To track crop depredation, respondents were asked whether they had ever experienced wildlife damage on their farms, which crops were targeted, and which species were responsible. Methods of protecting crops from wildlife were also examined. To track bushmeat harvesting, respondents were asked which type of wild meat people caught most frequently and which type of wild meat was "sweetest" to eat ["sweet" is the local Krio language word for delicious (Peace Corps 1985)]. Respondents were also asked which

types of wild animal species they would not eat. Respondents were asked specifically about interactions with the endangered pygmy hippo, which has proven to be exceptionally difficult to study using conventional data collection methods. Additional items captured demographic information (e.g., age, gender, education, resident status).

To address the second research objective, a subset of the 2010 respondents living near Tiwai Island (n = 14) were selected for participation in semi-structured interviews designed to explore the benefits, challenges, and overall feasibility of PPSR-style research in the region. With help from local Mende interpreters, the lead researcher conducted these interviews in May 2012. Interviews took place in the evening when participants were home from their farms.

Participants of the semi-structured interviews were chosen based on availability and willingness to participate. Nineteen people were approached for the survey and 14 people agreed to participate. Five people declined to participate because they said they were busy or had nothing to say about research. Two subsets of the participants emerged: trained field assistants employed by the researcher who had worked with the project for six months to one year and residents who were not paid by the researcher. All participants were familiar with the lead researcher. Qualitative analysis of the open-ended interview questions addressed three key elements of the PPSR process: (1) challenges of working with scientists, (2) contributions of local residents to research, and (3) factors affecting public participation in research.

RESULTS

Demographic Overview of Participants

Respondents in the 2010 intercept survey study consisted mostly of farmers and individuals with relatively low levels of education (Table 3.1), which is similar to populations in other parts of rural Sierra Leone (Klugman 2011). Respondents were mostly native to the

community they lived in and approximately half (56.4%) were male. Participants in the 2012 semi-structured interviews ranged in age from approximately 19-68 years old and lived in two of the eight host communities near Tiwai Island Wildlife Sanctuary. All but one of the interview participants was a male. Five interview participants worked directly with the on-going pygmy hippopotamus research, four worked as staff for Tiwai Island Wildlife Sanctuary, and the remaining five participants had minimal interaction with the project. All participants for these surveys had also responded to the 2010 intercept survey.

Objective 1: Characterizing Human-Wildlife Interactions

Crop depredation appeared to affect nearly all study respondents (99.4%) who contributed to the survey. About half of respondents (43.7%) reported the cane rat *Thryonomys swinderianus* as the largest source of crop damage, followed by red river hogs *Potamochoerus porcus* (Table 3.2). Cane rats were more generalist consumers, with respondents reporting damage to rice, cassava, and groundnuts, among other crops, whereas red river hogs were predominantly reported to damage cassava and sweet potatoes (Figure 3.2). Some respondents listed chimpanzees and other primates as major contributors to crop damage, but they were primarily reported only to damage cacao and oil palm cash-crop trees. Squirrels were generalist pests and were reported to consume corn, oil palm fruits, groundnuts, cassava and rice. Only 1.9% of respondents listed pygmy hippos as most damaging to crops; when asked which plants pygmy hippos consumed, respondents frequently answered "gbohui" *Triumfetta cordifolia* (58.7%), sweet potato (15.5%), and okra (15.4%). When asked specifically whether pygmy hippos damage crops, 27.8% agreed and 7.3% were unsure, suggesting that although pygmy

crops. For mitigating crop depredation, respondents mainly employed cable snare traps (99.8%) and fencing (99.6%), whereas scarecrows (7.5%) and making noise (5.0%) were less common.

Bushmeat appeared to be an important food source for most study respondents. For example, 83.0% of respondents agreed with the statement "wildlife provides food for people." Animals viewed as the sweetest meat included squirrel (35.8%), cane rat (30.7%), and porcupine (18.8%; Table 3.3). Pygmy hippo was a less desirable meat and was only reported by 0.39% of participants. However, when asked specifically if pygmy hippo meat was "sweet," 54.9% of respondents agreed, and 9.2% were unsure. Although most residents had access to domestic meat (i.e. chicken) as livestock owners, most respondents (69.1%) considered wild meat "sweeter" than domestic meat. Cane rat was reported to be the most frequently (87.6%) captured species by traps, followed by squirrel (5.6%) and Maxwell's duiker *Philantomba maxwellii* (4.1%; Table 3.4). Pygmy hippos were never captured in traps, and some residents believed pygmy hippos were able to bypass or break through most traps. Seventy percent of respondents admitted there were some wild meats they could would not eat, including red river hog (44.4%), monkey (42.1%), chimpanzee (26.9%), and snake (12.9%). Only eight participants (1.5%) listed pygmy hippos as an animal they would not eat.

Objective 2: Participant Perceptions Regarding PPSR Projects

Although the majority of study respondents did not engage in any formal scientific training or protocols prior to data reporting – a common element of citizen science projects in North America and Europe (Bonney et al. 2009) – the basic PPSR approach enabled local residents to provide previously unattainable information that addressed key research questions. Throughout the course of the semi-structured interviews, participants identified several key themes affecting PPSR in the region, including 1) challenges working with scientists, 2)

contributions of local residents to research, and 3) factors affecting public participation in research.

Challenges of Working with Foreign Scientists

Over half (57.1%) of semi-structured interview participants considered language or cultural differences obstacles when working with foreign researchers. Participants believed researchers did not listen to advice from them, and these cultural misunderstandings resulted in distrust and negative relations. As one respondent noted, "The community people and researchers don't listen to one another...And sometimes the community people are trying to enlighten them, telling them the facts, but the researchers don't trust us." Two participants relayed stories about occasions when misunderstandings arose between foreign researchers and local residents, leading to confrontation and resentment. Differing perceptions regarding punctuality and personal property issues were common sources of conflict between researchers and local people. According to one participant, "There are some traditional ways we people have, different than people coming from different countries...Whenever you employ a community worker, most of them cannot be on time. And the researcher needs their work done on time." Because local people mainly speak only Krio or Mende, language barriers were also a significant problem for respondents. "There are some people who cannot speak or read and write, so sometimes they find it difficult to talk with these researchers," noted one participant. Several participants highlighted adult literacy and language education as a potential solution for overcoming these problems. Participants also described another alternative: the training of a select group of individuals to assist in the research who could then communicate appropriate information and essential procedures or protocols to others. Overall, participants generally

advocated for foreign researchers to treat community people with respect in regards to culture, which would encourage trust and knowledge exchange.

Potential Contributions of Local Residents to Research

When participants were asked about specific contributions local communities could add to scientific research efforts in the area, several major themes emerged. One potential benefit of local involvement could be increased researcher access to community lands as well as access to indigenous knowledge of these ecosystems. Local knowledge also emerged as a factor affecting the success of a research project, and many participants reflected on how community guidance could inform research strategies. However, the support most frequently cited (85.7% of participants) were provision of physical labor, including cooks, trail cutters and field assistants. Another example was the contribution of participants to research methods. For example, input of villagers familiar with the local terrain allowed for design of a trap for safe physical capture of a pygmy hippopotamus in a separate on-going research project at Tiwai Island. Recounting this contribution, one participants remarked, "The community people give the idea on the way to catch the hippo without wounding, no death." Another participant expanded this local knowledge theme to discuss how they can serve as a critical line of communication between foreign researchers and local people. One participant discussed how the pygmy hippo project had influenced him to informally begin monitoring for pygmy hippo sign. Although many villagers were willing to contribute local knowledge and assist with the project, responses suggested residents were willing to contribute only if the researcher initiated contact.

Factors Affecting Public Participation in Research

Throughout the semi-structured interviews, participants expressed general agreement that scientific research was beneficial to their communities, either through income generation or

through educational capacity building. Many were able to highlight factors influencing community participation in research in the Tiwai Island region. Almost all participants referred to financial compensation as the greatest source of motivation for PPSR, although opinions differed as to whether villagers would consent to collect data for research without direct payment. One interview participant outlined the problem: "Only money makes us want to work with research, because if we are to do the job, and we have another thing to do at home, this research work can be difficult for us to do." In other words, local people may only be able to participate if the research and data collection/reporting responsibilities do not substantially conflict with their subsistence livelihoods. Six participants stated they would not voluntarily share information without compensation for their time. Other participants were willing to cooperate, but expressed concern many community members would not share their cooperative point of view. "If I have the knowledge, I will share it, although some people, except you give them money before they share knowledge," remarked one participant. A few of the participants believed residents would assist without compensation, but with the expectation of future rewards in the form of employment or money. Although participants primarily referred to monetary compensation, some participants also acknowledge other forms of compensation including community development, including school materials, soccer jerseys, or infrastructure improvement (e.g., water pump, community-meeting site). In short, it appears that long-term PPSR projects in the Tiwai Island would not succeed without some form of compensation or incentive measure in place.

However, financial compensation was not the only factor motivating participation in the study. Education obtained through participation was also seen as an important supplement to local knowledge. "Researchers are really important for Tiwai because they can make we know

many things about the forest, about the animals, I think about anything living within the community around Tiwai," noted one participant, highlighting the educational benefits of involvement in research. Participants also believed boosting the reputation and awareness of Tiwai Island internationally was a significant motivation for public cooperation. Several participants explained that if research was disseminated abroad, more researchers and tourists would be drawn to the area, which would lead to more employment and development rewards for the community. Furthermore, a few participants involved in the research explained participation in PPSR could, in itself, also generate interest in conservation. "You educate us to save this island. Now, we know the value of keeping wildlife. We are getting benefit out of it, like money. That alone, we are proud of that. It is well protected for now in our community...The more we are getting researchers, the more knowledge we create, and the more benefit we create from Tiwai."

DISCUSSION

Our research was designed to accomplish two goals. First, we sought to investigate the extent and the nature of human-wildlife interactions around a West African protected area. More importantly, we attempted to explore the feasibility of implementing a PPSR-style research project in a novel context – a biodiversity hotspot in a developing country.

Human-Wildlife Interactions

With most respondents identifying as farmers, and wildlife habitat decreasing as the need for agricultural land increases across the African continent, crop raiding will continue to affect local people through economic and opportunity costs (Dickman 2010). Farmers in other African countries such as Uganda and Zimbabwe have employed alternative methods to mitigate wildlife conflicts, including guarding fields to repel primates (Hill 2000), using botanical repellants such

as capsicum peppers for elephants (Osborn 2002), and compensation programs by both governmental or nongovernmental organizations for lost yield (Nyhus et al. 2003). Farmers in our study used cable snares as a primary method of crop damage prevention. While cable snares appeared to mainly capture prolific species like cane rat, snares are nonselective and may incidentally capture threatened species (e.g. zebra duiker). Often, farmers will consume wildlife captured in their traps; however, evidence suggests many animals caught in cable snares may be lost to decomposition (Noss 1998b). Furthermore, threatened species like the endangered chimpanzee *Pan troglodytes* may also be targeted (Bowen-Jones and Pendry 1999). While pygmy hippos are not a major crop pest, increasing human populations and subsequent need for agricultural encroachment could exacerbate current levels of crop depredation, and result in heightened human-hippo conflict. Due to the high prevalence of threatened species in the Tiwai Island area, alternative measures for both food and cash crop protection among farmers should be investigated.

Our study investigated bushmeat consumption near a protected area in southeastern Sierra Leone. The most often captured species in our study reflected those found in Davies and Brown (2007), where 90% of species caught for consumption were habitat generalists (e.g. those found in both bush fallow and forests). Furthermore, Subramanian (2013) reported animals like the cane rat *Thryonomys swinderianus* and bushbuck *Tragelaphus scriptus* as among the most frequently preferred game species in Sierra Leone. These species are likely more resilient to hunting pressure than habitat-specific species because of their flexible diet (Mainka 2002). During the focus groups, before commencement of the surveys, the only people who had ever seen a pygmy hippopotamus were the elderly, who had observed hippos only in their childhood, indicating an alarming decrease in hippo populations within the last few decades. The war may

have contributed to this decline (Hanson et al. 2009). Others have found that when larger, more profitable animals like the pygmy hippo become scarce, smaller animals are targeted until all species become depleted or even extirpated (Bennett et al. 2002, Fa et al. 2005).

Local Perceptions of Public Participation in Research

Increasing evidence indicates incorporating the knowledge of local citizens and experiences into scientific research may increase awareness of underlying environmental processes affecting human livelihoods and conservation efforts around the world. For example, Mulder et al. (2007) collaborated with elders and youth in Tanzania to map traditional landmarks, which motivated community interest in local history and promoted awareness of sustainable land use. Whereas traditional environmental outreach is generally a one-sided topdown approach, citizen science models allow for interaction and information sharing both ways (Braschler 2009). In fact, this is specifically what PPSR projects are intended to accomplish: the generation of learning outcomes and the construction of social capital enhances collective problem solving (Cooper 2012). Effective coproduction of knowledge is difficult to evaluate (Cornwell and Campbell 2012), however, and many questions remain regarding the potential value of PPSR as a science education tool (Bonney et al. 2009a).

In this study, results suggested interactions between researchers and local citizens may have generated educational benefits. For instance, several participants mentioned the research program had enhanced their awareness of the value of conservation and increased their sense of pride for the protected Island close to their homes. As with other assessments of citizen projects, however, it is not clear how these changes influenced overall environmental attitudes or understanding of the broader scientific process (Brossard et al. 2005). Furthermore, conclusions from a small subset of interview respondents may not be indicative of the broader population.

Regardless of observed benefits, it is important to consider how PPSR projects can be designed and adapted to accommodate new audiences (Bonney et al. 2009b). While attempting to implement and evaluate of a PPSR approach within novel context (i.e., a biodiversity hotspot in rural Africa), researchers in this study revealed several challenges that may affect the design of future PPSR programs in similar contexts.

Citizen science research has shown that the variability of observer skills can affect data accuracy, especially with mainly illiterate populations (Fitzpatrick et al. 2009). Interview data in this study supported this finding, with many respondents noting that miscommunication and misinterpretation were persistent problems during the project. Future PPSR efforts in low-income developing countries should consider using translators with formal education whenever possible to help facilitate interactions with individuals lacking education. Although our interviewers and translators had attended secondary school and had known the lead researcher for more than one year, interviews suggested language and cultural barriers may still have confounded some results. The findings corroborate other assertions that citizen science data collection, particularly in developing countries, must be as straightforward and standardized as possible to minimize bias and allow for validation (Silvertown 2009).

Another significant challenge is the apparent need for incentives to influence participation in research studies, a theme that repeatedly emerged with most of our interview participants. Citizen science, by definition, relies on volunteer, unpaid, labor (Cohn 2008), and understanding the motives of these volunteers is a critical part of the recruiting, engaging, and ultimately retaining program participants (Chu et al. 2012). For example, Rotman et al. (2012) showed initial participation in a U.S.- based online citizen science project stemmed from personal interest and hobbies (i.e., the Encyclopedia of Life), continued involvement was related

to feelings of attribution and acknowledgment. In developing countries, however, these motivations may be quite different. For people living a life of subsistence in impoverished areas, volunteerism is rarely feasible. Therefore, extra incentives may be needed to encourage citizens to interact with scientists and contribute to studies, allowing the participants be compensated for lost time on their domestic work. Nevertheless, extreme care must be taken for compensation not to bias results.

Like many African countries, Sierra Leone has a collectivist culture, where in-group cohesion outweighs the needs of an individual (Triandis 2001, Shaffer 2009). Hence, there are major potential outlets for collaboration that may benefit the greater good, including nonfinancial compensation in the form of community development benefits or trainings, which could represent a viable substitute for individual rewards. Our project experimented with this concept by donating soccer jerseys to two communities in exchange for in-kind labor with moderate success. Other non-monetary awards mentioned were communal meeting places and school supplies. Another solution would be to engage primary or secondary children and directly involve them in ecological monitoring programs. Braschler (2009) used this model to assess insect diversity (particularly ants) in South Africa, and the results have been impressive. Citizen science initiatives like this highlight the value of utilizing existing infrastructure and cultural or institutional frameworks (in Braschler's case, educational curriculum) to increase scientific capacity and achieve conservation goals.

CONCLUSION

In this study, a PPSR approach enabled scientists to address a critical conservation issue in a challenging context. Strategic interactions and communication with local residents helped researchers to better understand human-wildlife interactions around a protected area in Sierra

Leone, including species viewed as crop pests and those targeted for bushmeat hunting. Without the assistance of local villages who contributed data via intercept surveys, learning about the broad scope of human wildlife interactions in the area would have been difficult. The advantages of PPSR-generated data are especially evident for questions involving elusive species like the pygmy hippopotamus, which have proven to be notoriously difficult to study using conventional approaches. Though respondents were not formally trained in scientific methods and did not actively record crop depredation events or bushmeat harvesting events as they occurred, these individuals had the capacity to retroactively report activities to researchers. Their contributions were therefore a critical part of the scientific process. Future studies could implement a more proactive PPSR model whereby by monitoring methods and protocols are established prior to data collection, resulting in a more standardized scientific process common in many citizen science projects in developed countries. Integration of IK and PPSR may be especially difficult in developing countries where traditional concepts and Western science may not always be methodologically or conceptually compatible (Leach and Fairhead 2002). Nevertheless, citizen science may represent an opportunity for synergistic interactions to promote positive humanwildlife interactions and foster biodiversity conservation in local communities. In the future, simple contributory PPSR projects like ours that involve very basic monitoring and reporting could develop into collaborative programs relying on co-creation between scientists and citizens, providing the public more ownership in the entire process and likely yielding more sustainable outcomes (Shirk et al. 2012). Overall, our research sheds some light on the value of citizen science as well as the challenges and obstacles remaining as PPSR-style projects expand to encompass new audiences in developing countries. By providing useful information to researchers while simultaneously encouraging residents to develop an increased awareness of

local conservation issues, data in this study illustrate the multifaceted benefits of citizen science. Future research could build upon this preliminary framework to create PPSR projects more collaborative in nature, giving the public increased ownership throughout the entire scientific process and ultimately yielding sustainable outcomes for rural residents and ecosystems they inhabit.

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Table 3.1. Demographic characteristics of study participants (August - December 2010, n = 522) in villages around the Tiwai Island Wildlife Sanctuary, Sierra Leone.

Variable	Survey (%)
Gender	
Female	43.6
Male	56.4
Mean Age	44.8 (16.40 SD)
Age	
18-29	13.4
30-39	29.2
40-49	24.4
50-59	11.5
60+	21.5
Occupation	
Farmer	89.8
Fishermen	0.4
Miner	0.6
Merchants	4.2
Other	4.4
Education	
None	41.7
Arabic/Primary	48.2
Secondary	10.1
Livestock	
Own livestock	82.8
No livestock	17.2
Resident Status ^a	
Native	88.4
Immigrant	11.6
Mean family size	7.6 (4.37 SD)

^aResidents born in the surveyed or tributary village were defined as native, whereas an immigrant was defined as somebody born outside this area (Davies and Richards 1991).

Table 3.2. Wildlife species ranked as the most damaging to agricultural crops as reported by study participants in villages around the Tiwai Island Wildlife Sanctuary, Sierra Leone. (August-December, 2010, n = 522)

Species (Rank)	Species Name	% Rated Most Damaging
1. Cane rat	Thryonomys swinderianus	43.7%
2. Red river hog	Potamochoerus porcus	30.8%
3. Squirrel ¹	Sciuridae	5.8%
4. Bird ¹	N/A	4.8%
5. Monkey ¹	N/A	4.6%
6. Chimpanzee	Pan troglodytes	3.5%
7. Brush-tailed porcupine	Atherurus africanus	2.9%
8. Forest buffalo	Syncerus caffer	1.3%
9. Pygmy hippopotamus	Choeropsis liberiensis	1.9%
10. Bushbuck	Tragelaphus scriptus	0.4%

¹Not identified to species due to local name confusion or misidentification

Table 3.3. Wildlife species ranked as the sweetest bushmeat as reported by study participants in villages around the Tiwai Island Wildlife Sanctuary, Sierra Leone. (August-December, 2010, n = 522)

Species (Rank)	Scientific Name	% Rated
1. Squirrel ¹	Sciuridae	36.1
2. Cane rat	Thryonomys swinderianus	30.9
3. Brush-tailed porcupine	Atherurus africanus	18.9
4. Rabbit ¹	N/A	3.9
5. Maxwell's duiker	Philantomba maxwelli	2.3
6. Red river hog	Potamochoerus porcus	1.5
7. Monkey ¹	N/A	1.4
8. Bushbuck	Tragelaphus scriptus	1.2
9. Water chevrotain	Hyemoschus aquaticus	1.0
10. Mongoose ¹	Herpestidae	1.0
11. Royal antelope	Neotragus pygmaeus	1.0
12. Pygmy hippopotamus	Choeropsis liberiensis	0.4
13. Black duiker	Cephalophus niger	0.2
14. Crocodile ¹	Crocodylidae	0.2
15. Yellow-backed duiker	Cephalophus silvicultor	0.2

¹Not identified to species due to local name confusion or misidentification

Table 3.4. Wildlife species ranked as captured most frequently as reported by study participants in villages around the Tiwai Island Wildlife Sanctuary, Sierra Leone. (August-December, 2010, n = 522)

Species (Rank)	Scientific Name	% Rated
1. Cane rat	Thryonomys swinderianus	87.6
2. Squirrel	Sciuridae	5.6
3. Maxwell's duiker	Philantomba maxwelli	4.1
4. Brush-tailed porcupine	Atherurus africanus	1.2
5. Red river hog	Potamochoerus porcus	0.8
6. Monkey ¹	N/A	0.6
7. Bushbuck	Tragelaphus scriptus	0.2

¹Not identified to species due to local name confusion or misidentification


Figure 3.1. Map of Tiwai Island, Sierra Leone, showing communities along the Moa River where villagers were surveyed during August – December 2010. [Inset displays the location of Tiwai Island within Sierra Leone.]



Figure 3.2. Proportion of total study participants who reported damage to various crops by the five most common mammalian crop pests in the Tiwai Island area, Sierra Leone (August – December 2010, n = 522).

CHAPTER 4

EVALUATION OF RADIO TRANSMITTER ATTACHMENTS FOR THE PYGMY HIPPOPOTAMUS¹

¹Conway, A.L., deMaar, T.W., Hernandez, S.M. and J.P. Carroll. Submitted to *Zoo Biology*, 04/22/13.

ABSTRACT

The pygmy hippopotamus *Choeropsis liberiensis* is an endangered species endemic to the Upper Guinea Forests of West Africa. Pygmy hippos are challenging to study in the field because they are rare, solitary, and nocturnal. Therefore, indirect methods of observation, including radio (or GPS) telemetry, may contribute data necessary for a better understanding of pygmy hippo ecology. However, the unique morphology of pygmy hippos presents obstacles for radio transmitter attachment. The objective of this study was to develop and test radio transmitter attachments on captive pygmy hippos for subsequent use in situ in West Africa. We tested four transmitter designs on two captive female pygmy hippos at the Gladys Porter Zoo, Texas: a 1) hock mount 2) harness 3) neck collar, and 4) PVC modified neck collar. We physically immobilized two pygmy hippos using a squeeze chute for transmitter attachment. The hock and harness attachments detached from the pygmy hippo and the neck collar resulted in significant abrasion. The PVC modified neck collar caused minimal abrasions around the neck. We recommend the PVC modified neck collar because it remained securely on the pygmy hippo and had the least potential for adverse effects. However, we advise modifications depending on the size of the individual. Results from this study can guide future studies for radio transmitter placement in both captive settings and in the field.

STATEMENT OF THE PROBLEM

The pygmy hippopotamus *Choeropsis liberiensis*, hereafter pygmy hippo, is an endangered species endemic to West Africa. Major threats to their survival include agricultural expansion, poaching, and human-wildlife conflicts (Mallon et al. 2011). As human populations increase across pygmy hippo range with subsequent degradation of habitat, there is an urgent need to understand the complex issues facing their conservation. A preliminary step is to

understand habitat requirements and movements of pygmy hippos. Due to their rarity, aquatic lifestyle, and nocturnal behavior, detection of pygmy hippos is problematic and consequently the basic biology of pygmy hippos is not well known. Visual observations of pygmy hippos are infrequent, even by people living near prime habitat (Hillers and Muana 2011); thus, monitoring with direct observations can be cost prohibitive and labor intensive.

One method used to track movements of cryptic and rare species is radio telemetry, which generates valuable information on demographics, resource selection, and home range size (Kenward 2001). However, species with atypical body shapes and behaviors present challenges for radio transmitter attachment (Walker et al. 2012). Radio telemetry assumes the attachment of a tracking device does not affect behavior, energy budgets and survival of individuals, which is a particular concern for endangered species (Durnin et al. 2004). However, studies indicate tracking devices may affect the individual both biologically and behaviorally. For example, collars applied to black rhinoceros Diceros bicornis caused abrasions on approximately 15% of collared animals, leading authors to dispute the effectiveness of routine radio collaring (Alibhai and Jewell 2001). Ear tag transmitters used on large mammal pose problems for long-term studies because of the potential for tag detachment (Hofmeyr 1998). Surgical implants require aseptic surgical techniques and post-surgical monitoring, both of which are problematic in the field (Kenward 2001). For example, implanted data loggers in elephant seals Mirounga angustirostris showed inflammatory response and required removal (Green et al. 2009). Furthermore, signal strength in implanted transmitters can attenuate, as found in black bears Ursus americanus (Koehler et al. 2001).

With little known about pygmy hippos, radio telemetry may yield insight on habitats considered a high priority for conservation. However, their unique morphology creates multiple

challenges for transmitter attachment. Hippo skin produces an alkaline mucin that acts as moisturizer, antiseptic, and sun protection (Hashimoto et al. 2007). However, this secretion also interferes with transmitter attachment, as neck collars can slip off and glued transmitters will not bond easily. Furthermore, a neck and head of similar circumference prohibits use of a standard strap neck collar because the collar may slip, or if too tight, could cause abrasion.

The only radiotelemetry study of pygmy hippos used collar type attachments; however, to our knowledge, no information exists on the collar effects (Bülow 1987). A recently created Conservation Strategy by Mallon et al. (2011) advocates development of standardized field techniques and Collen et al. (2011) suggests radio telemetry to estimate home range sizes of pygmy hippos. However, evaluation of attachments *ex situ* before application in the field is ideal for species that may have adverse reactions (Kenward 2001). Furthermore, evaluating attachments on captive animals allows for close monitoring of the individual's physical condition and behavior. The objective of this study was to develop an attachment method for a radio transmitter on captive pygmy hippos for subsequent *in situ* use.

DESCRIPTION OF THE PROBLEM

Ex Situ Site

We conducted radio transmitter trials at the Gladys Porter Zoo in Brownsville, Texas in March and December 2010. We deemed two captive females suitable for the study because they had generally calm temperaments, were housed off-exhibit, and were post-reproductive (Gladys Porter Zoo 2010). One female (F1) was wild-caught in 1971 and estimated to be 44 y old and the other adult female (F2) was captive-born in 1973. Both study animals lived in separate stalls but had contact with neighboring hippos through cage bars. Each stall measured approximately 3.6 m x 3.6 m and contained a water bowl. A group comprised of a male, female and calf was in a third stall between the study hippos, but were released into the outdoor exhibit each morning and returned at sundown. We considered the family group unsuitable for the study because they were on exhibit daily and the male had a history of aggressive behavior.

Transmitter Attachment

We evaluated four transmitter designs including a: 1) hock mount 2) body harness 3) neck collar, and 4) PVC modified neck collar. Wildlife Materials, Inc. (WMI, Murphysboro, IL USA) constructed the first three designs from a flat strap of Biothane, a flexible material typically used for horse tack. Each design included an adjustable strap fastened with brass plate hardware (Figures 4.1a, 4.1b and 4.1c). We constructed the harness design using an adjustable Biothane strap and added nylon strap (Figure 4.1b). The modified neck collar was constructed using ½-inch braided Polyvinyl Chloride (PVC) hosing sheathed in 3 mm neoprene for added friction to inhibit slipping and fastened with a PVC coupler (Figure 4.1d). All designs contained a sham transmitter and whip antenna. Magnets of similar size and weight substituted for batteries typically used to minimize toxicity in the event of ingestion. Sham transmitters were constructed to mimic the WMI Model 31100 (neck collars and harness, weight 350 g, battery life 807 d) and 3140 (hock mount, weight 160 g, battery life 550 d).

On 23 March 2010, we transported both hippos by trailer to a holding barn with two separate enclosures. On 24 March, we physically restrained hippos individually in a metal squeeze chute. We attached the hock mount design to the right hind limb of F2. However, upon return to her enclosure, the hock mount detached. On March 25, we returned F2 to the chute to attach the harness design. We then transported F1 to the squeeze chute and attached the Biothane neck collar. F1 remained in the holding barn overnight and returned to her enclosure the next day for further behavioral observation. In December 2010, we placed the PVC modified neck collar

fastened with superglue and coupler on F2 in her primary enclosure (Figure 4.1e). As a distraction, zookeepers placed food in the enclosure near the fence during the procedure and no physical restraint was required.

We used an ethogram approach (Blowers et al. 2010) with behaviors similar the common hippopotamus (*Hippopotamus amphibious*; Table 4.1). We did not record post-attachment behavior observations for the hock mount or harness attachment. For the Biothane neck collar attachment on F1, we recorded behavioral observations from 21 to 27 March 2010 during 30 min observation periods in one min increments (1-3 times / d) in a One-Zero sampling method (Altmann 1974). Observations for F1 totaled 16 periods, with seven times before and nine times after neck collar placement (480 min total). In addition to common behaviors like defecating, locomotion, and yawning, we monitored neck collar-directed behaviors such as rubbing transmitter against enclosure objects and change in appetite. Zoo staff made only general behavioral observations for the PVC modified neck collar.

Statistical Analysis

We analyzed frequency data using SPSS *v*. 21.0 (Statistical Package for the Social Sciences, Chicago, IL USA) and we analyzed differences in intervals before and after transmitter attachment using Wilcoxon Signed Rank Tests, with differences significant at p < 0.05.

DEMONSTRATION OF EFFICACY

Transmitter Attachment

The hock mount design placed on F2 failed within about five minutes of attachment. The anatomy of the hock allowed for it to fall off easily. The harness attachment design we attempted slipped immediately and caught underneath her legs while in the chute. She would not stand again, even when encouraged. We removed the harness and returned F2 to her enclosure.

We attached the Biothane strap neck collar to F1 on 24 March 2010. On 25 March, the collar shifted and the antenna pointed downward with the right ear trapped underneath the collar. However, the next day the collar returned to a normal position and the ear was free. Zookeepers noted skin abrasions within two days of attachment, and on 2 April, after a total 12 days, we cut the collar off due to full-thickness skin abrasions behind both ears and on top of the head.

On 1 December, the zoo veterinarian attached the PVC modified neck collar to F2. However, the collar appeared loose, and the hippo pulled the collar off approximately two hours after placement. After removing 5 cm of hosing, the veterinarian reattached the PVC modified neck collar on 3 December; however, the collar fell apart at the seam three days later. Reattachment occurred again on 18 December using an Epoxy adhesive for a stronger bond. The collar remained on the hippo until 10 January 2011 (24 d), after which the collar fell apart at the PVC coupler. The pygmy hippo had superficial abrasions on her neck after detachment. *Behavioral Observations*

We did not record behavioral data for F2 because neither the hock nor the harness attachment design held for > 5 min. With the Biothane neck collar, F1 rubbed her head on enclosure objects like the food bowl or along the wall significantly more frequently after than before collar attachment (z = -3.59, p < 0.001, Wilcoxon signed rank text); however, this behavior decreased as time progressed (from 0.43 to 0 times / min, after three days). She yawned significantly less after the transmitter was attached (z = -2.86, P < 0.001, Wilcoxon signed rank text; Figure 4.2). One day after collar attachment, F1 did not eat food placed in her enclosure. However, 48 h after collar placement her appetite returned to normal. No other behaviors changed significantly before and after collar attachment. While we recorded no specific behavior

data for F2 for the PVC modified neck collar, zookeepers reported the hippo appeared comfortable during the PVC modified neck collar trial with minimal changes in behavior.

DISCUSSION

Pygmy hippos pose challenges for transmitter attachment due to body shape, unique skin, and aquatic lifestyle. Our study highlighted the need to consider these factors when determining the best attachment method for radio-tracking devices. Of the four designs we tested, the PVC modified neck collar appeared the best option. Although we securely fastened the hock mount, the tapered leg shape prohibited the mount from staying in position. A harness design also caused multiple issues as in our study; the harness can catch on the fore legs, interfering with movement, and involves more surface area (when compared to a collar), resulting in a higher probability for abrasion and snagging on vegetation.

All attachment designs were well within the accepted transmitter-to-body weight ratios of < 5% of estimated body weight (Kenward 2001). However, the Biothane neck collar resulted in serious abrasions, which may be due to the individual animal rubbing the collar on enclosure objects. Thus, we cannot recommend this attachment for use in the field. Although Bülow (1987) used strap neck collars, other design, including a tubular design, were not tested for use on pygmy hippos. Our results suggest a modified neck collar made of a PVC hose may be a viable method for attachment. However, one of the main constraints is the inflexibility of the material. Therefore, we recommend using this type of collar only on a fully-grown adult, or to add modifications such as a collar expansion or weak link for the collar to breakaway. Further considerations for *in situ* placement include securely bonding seams by placing screws through the connector for added stability or encapsulating the joint in Epoxy. Flexible and humidity-resilient materials like scuba hose may warrant further investigation.

While captive trials allow for close monitoring of pygmy hippo behavior, our placement procedure had limits. Chemical immobilization of pygmy hippos is notoriously difficult and risky, even in captive settings (Miller 2007). Therefore, we considered physical restraint the best method. Without chemical immobilization, attach was difficult on an alert animal as they may become aggressive and inflict serious injury. However, for *in situ* placement, chemical immobilization will be necessary (Bouts et al. 2012). Future studies in the field can use these results as a guideline for radio transmitter attachment of pygmy hippos in the field.

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Table 4.1. Ethogram variables similar to Blowers *et al.* (2010) used to evaluate captive pygmy hippopotamus (*Choeropsis liberiensis*) behaviors at Gladys Porter Zoo, Texas

Focal Behavior	Description
Inactive Standing	Animal not moving while standing
Inactive Recumbent	Animal not moving while recumbent
Sleeping	Animal recumbent with eyes closed
Ear wagging	Animal wagging ears
Locomotion	Animal walking around enclosure
Drink	Animal drinking water out of water bowl
Defecate	Animal defecating
Urinate	Animal urinating
Yawn	Animal opening mouth wide and exposing the tusks
Rubbing	Animal rubbing part of body on enclosure items
Feeding	Animal consuming pellets or alfalfa hay
Chomping	Animal opening and closing moth as if chewing
Vocalizing	Snorting, snoring or other vocalization





a.

b.



c.



d.





Figure 4.1. a.) Hock mount transmitter model on captive female pygmy hippopotamus (*Choeropsis liberiensis*) F2, b.) Harness transmitter model on captive pygmy hippopotamus c.) Biothane neck collar transmitter model on captive female pygmy hippopotamus F1 in March 2010 d.) Modified Polyvinyl Chloride (PVC) neck collar on F1 in December 2010 at the Gladys Porter Zoo, Texas e) Final design of the modified PVC neck collar for use with *in situ* pygmy hippopotamus



Figure 4.2. Frequency per minute interval of yawning and head rub behavior on enclosure objects by a captive female pygmy hippopotamus *Choeropsis liberiensis* before and after neck collar attachment in Gladys Porter Zoo, Texas using Wilcoxon Signed Rank Tests for significance (mean \pm SE).

CHAPTER 5

PHYSICAL CAPTURE TECHNIQUES FOR THE PYGMY HIPPOPOTAMUS CHOEROPSIS LIBERIENSIS ON TIWAI ISLAND, SIERRA LEONE¹

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ABSTRACT

Elusive and rare species are often challenging to study because they have low detection rates, which can result in high personnel and time costs as well as biased estimation of parameters. Sampling techniques such as radio telemetry allow for remote observation for estimation of demographic parameters, survival and movement. However, placement of a radio transmitter requires an animal to be physically and often chemically immobilized. Certain capture methods may be suitable for some wildlife species, such as bomas (capture corrals) or darting for the common hippopotamus Hippopotamus amphibious. However, for more cryptic species like the pygmy hippopotamus Choeropsis liberiensis, who are solitary and nocturnal, novel methods should to be tested *in situ*. Our study sought to evaluate and implement pitfall traps, which are holes excavated in the ground and camouflaged, for safe capture of a wild pygmy hippopotamus for radio transmitter attachment on and around Tiwai Island, Sierra Leone. A trial period from August to October 2010 resulted in the safe capture of one male pygmy hippopotamus. Pygmy hippopotamus sign was observed during subsequent trap capture and closure periods, and near-captures occurred in each of the three capture periods. Although no pygmy hippopotami were captured during post-trial capture periods, we believe trap modification and a longer capture period will lead to successful physical capture and radio transmitter attachment.

INTRODUCTION

Conservation of endangered species relies on accurate and detailed knowledge of their behavior, distribution, habitat use, movement patterns and conservation threats. Cryptic and rare species are challenging to study *in situ* because they display behaviors that make them difficult to observe (e.g. solitary, nocturnal), live in logistically difficult locations, and have low

population densities over a broad scale (Thompson 2004, Ellison and Agrawal 2005). Innovative technology, including remote sensing, camera trapping, and radio telemetry can aid in detection of cryptic species and allow for unbiased inferences on a study population (Kerr and Ostrovsky 2003, Rowcliffe and Carbone 2008), yet require physical capture and handling.

One of the most elusive species in Africa, the pygmy hippopotamus *Choeropsis liberiensis*, is an endangered species endemic to the Upper Guinea Forests of West Africa. The pygmy hippopotamus (hereafter pygmy hippo) is rare, secretive and has a semi-aquatic and nocturnal lifestyle making its detection a challenge. Consequently, little is known about its basic biology and behavior in the wild, including the use of habitat and movement patterns across the landscape. Urgent threats to pygmy hippos include habitat loss and fragmentation, poaching, and human-wildlife conflict (Mallon et al. 2011).

The Upper Guinea Forests are designated a global hotspot for conservation (Myers et al. 2000). However, much of the original forest cover has been lost due to anthropogenic forces, including agricultural expansion, timber extraction and urbanization (Norris et al. 2010). As human populations increase across the region and suitable habitats are subsequently degraded or destroyed, a better understanding of habitat use and movement patterns of pygmy hippos is urgently needed.

Attachment of tags or radio transmitters requires the animal to be physically handled, and several factors should be weighed when deciding on a capture technique, including the ability of the technique to catch a rare animal, logistical issues, and overall animal welfare. For endangered species in particular, the benefits of capturing and handling must be weighed against stress to the animal and potential mortality (Osofsky and Hirsch 2000). Physical and chemical immobilization may lead to capture myopathy, traumatic injuries or death (West et al. 2008, Sikes and Gannon

2011). Large mammals experience further complications from prolonged recumbency, including thermoregulation, hypoxemia, respiratory and cardiovascular depression (West et al. 2008). In addition, dangerous animals such as pygmy hippos pose a significant threat to researchers because of the potential for inflicting serious injuries by charging, biting and crushing (Steck 2008).

Various methods have been implemented to safely capture large mammals, including darting for the common hippopotamus *Hippopotamus amphibius* (Pienaar 1967), containment in bomas for black rhinoceros *Diceros bicornis* (Morkel and Kennedy-Benson 2011), and box traps for feral swine *Sus scrofa* (Long and Campbell 2012). For example, the common hippopotamus (*Hippopotamus amphibious*) is often immobilized in a boma after enticement with feed (e.g., lucerne, hay). For species like the Sumatran rhinoceros *Dicerorhinus sumatrensis*, lowland tapirs *Tapirus terrestris* and okapi *Okapia johnstoni*, where bomas would be impractical to construct, pitfall traps have been used (Lindsey et al. 1999, Sectionov 2007, Medici 2010).

Pitfall traps may also be appropriate for a large secretive animal like pygmy hippos. In fact, Schomburgk (1912) and Van den Brink (1964) used pitfall traps to capture pygmy hippos for exportation from Liberia and Côte d'Ivoire in the early 20th century. Many of these individuals were transported to Europe and the United States and formed the founder population of the current zoological population (Steck 2008). Hentschel (1990) evaluated several capture techniques for pygmy hippos in Taï National Park, Côte d'Ivoire including cable snares, box traps, and pitfall traps. Eleven pygmy hippos captured using pitfall traps were translocated to Azagny National Park. Six of these translocated individuals were monitored for three to six months via radio telemetry or tracking (Bülow 1987, Roth et al. 2004) and none appeared to suffer any ill effect from the trapping technique. No further study has been conducted using radio

telemetry of pygmy hippos since this time, and the last known capture for zoo animals was approximately 1981 (Steck and Pagan 2009). To our knowledge, no review exists of a trapping method for pygmy hippos. The objective of this study was to 1) determine an effective bait to attract pygmy hippos to camera and pitfall traps, and 2) develop and evaluate a safe, effective protocol for physical capture and subsequent chemical immobilization and attachment of a radio transmitter of pygmy hippos in Sierra Leone.

STUDY AREA

Tiwai Island is a 12-km² island on the Moa River in southeastern Sierra Leone (Figure 5.1). The Island is adjacent to the western end of the Gola Forest National Park and southern end of the Kambui Hills Reserve. Elevation on the Island ranges from 80-110 m above sea level with moderate sloping into four drainage basins (Eichenlaub 1989). Soils are generally sandy with low fertility. Rainy season lasts from May to October and averages approximately 3000 mm per year, with the majority falling between July-August. The surrounding Moa River rises approximately 2 m each year during rainy season. Geographic faulting causes the river to branch around the island and hundreds of smaller islands.

Vegetation is a mosaic of bush fallow, palm swamps, and old secondary forest (Oates et al. 1990a). Old forest covers approximately 60% of the island, with high plant species diversity and a multi-layered canopy. Secondary forest comprises about 30% of the island and is generally the result of agriculture occurring before researchers activities began in 1982. These forests are much thicker and contain trees with low stature, climbing shrubs and woody plants (Whitesides 1989). Swamps dominated by *Raphia gracilis* also occur along interior drainage channels. Several of the smaller islands surrounding Tiwai Island are mainly bush fallow, characterized by

regenerating growth from agricultural fields. Bush fallow type vegetation also occurs in locations on Tiwai with open canopy from windfalls.

The Island is divided by a grid system of transects running north-south and east-west spaced 50 m apart. However, the northern portion and large portions of the south of the Island do not have trails and are generally inaccessible via foot travel. While there are no permanent settlements on Tiwai, six communities surround the island across the Moa River. Rice fields interspersed with groundnut, cassava, coffee and cocoa plantations are found on the mainland (Davies and Richards 1991).

METHODS

Bait Trials

As part of a broader study to determine the occupancy rates and habitat use of pygmy hippos on Tiwai Island, near-infrared digital game cameras (Moultrie Game Spy 4.0[™] and Bushnell Trophy Cam[™]) were used to document pygmy hippo presence on and around Tiwai Island from February 2009 to June 2009 (field season 1) and from May 2010 to July 2011 (field season 2). Cameras were placed in areas of frequent pygmy hippo sign, including dung, feeding sites, and foot tracks in both seasons. Both still shots and video were taken, depending on type of camera used.

To increase visitation to traps, cameras were augmented with bait. Bait choice was determined on previous reports of food preference by pygmy hippos (Steck 2008) and limited by availability and the logistically challenges associated with a resource-poor, remote location. During the first field season, cameras were placed at 44 locations of which twenty-one stations were baited with bananas, ten with pumpkin, seven with okra, five with mango and one with pineapple. Perfume, salt licks, palm nuts from the *Elaeis guineensis* palm, and sweet potato

Ipomoea batata leaves were added as attractants and baits in field season 2. Okra was planted a week before the camera survey began and was protected from animals with a rattan covering until the plant matured. Perfumes included Calvin Klein Obsession for Men[™] which has been used in other studies to attract wildlife (Mickleburgh et al. 2003) and two locally available generic brands. Cameras were also placed facing sweet potato plants already growing in nearby fields tended by local farmers. Salt was saturated with water onto a porous log to create a salt lick. Bait or attractants were replenished every two days.

Pitfall Trap Trials

Pitfall traps were located on and around Tiwai Island Wildlife Sanctuary (Figure 5.1). Capture periods took place from August-October 2010, January-February 2011, April-May 2011, and the entire month of May 2012 (Table 5.1). From February-April 2011 and from April-May 2012, traps were constructed and closed with strong sticks and a mat to allow an animal to cross. Local hunters were consulted on construction of pit traps because of their experience using similar traps to hunt large game (A. Conway, unpublished data). Trap dimensions were similar to those described by Schomburgk (1913) and Medici (2010). Traps during 2010 and 2011 measured 2.0 m long X 1.0 m wide X 1.5 m deep orientated along an animal trail. Those during May 2012 were enlarged to 2.0 m long X 1.0 m wide X 1.8 - 2.0 m deep (Figure 5.2a). All open traps were covered with notched supportive cross-sticks and mats camouflaged with forest debris, including dead leaves and small sticks (Figure 5.2b). Closed traps were covered with strong, unnotched cross-sticks, a mat and a thin layer of soil to facilitate monitoring of animal sign.

Pitfall traps on islands surrounding Tiwai Island were accessed by canoe or by crossing natural rock bridges on foot. Traps on the northwest side of the island were accessed via

motorboat. All traps were located within 3 km of the research station to allow for a rapid response by the capture team. Field assistants checked open traps twice a day, at 07:00 and 17:00, for animal presence or sign inside or near the traps. Sign included footprints, dung, evidence of active feeding, and visual or auditory observations. Camera traps were set on several pitfall traps to record animal activity either by photograph or by video. Communication about the status of traps was relayed to the immobilization team via two-way radio.

On 18 August 2010, nine traps were constructed for a trial period on and around Tiwai Island to evaluate effectiveness of pitfall traps to capture pygmy hippos. The trial period was defined as the time between the opening of a trap and the time the trap was covered and deactivated. Traps were located based on camera trap evidence of use, observed pygmy hippo sign or by recommendations from local residents (in the case of traps on the mainland). Six traps were located on frequented pygmy hippo trails on Tiwai Island and three were near agricultural fields belonging to the local community. Traps were closed and filled permanently on 28 October 2010.

On 15 January 2011, an additional 14 traps were constructed for capture period 1 on Tiwai Island and surrounding smaller islands with the objective of capturing, immobilizing and placing a radio transmitter on multiple pygmy hippos. On 3 February 2011, traps were closed but continued to be monitored for animal sign until 10 April 2011. Six additional traps were constructed during this time to increase likelihood of capture for capture period 2, which began on 11 April 2011. Twenty traps were opened for this period until 29 April 2011, when they were closed and filled in permanently. Traps were located on Tiwai Island and the smaller islands.

From 24 March - 13 April 2012, 23 traps were constructed but not opened with the objective of allowing animals to acclimate to the presence of the trap. Salt licks similar to those

used in bait trials were placed on ten traps, and all traps were monitored for sign. Twenty-one of these traps were opened on 4 May 2012 and were monitored twice daily for pygmy hippo sign for capture period 3. Traps were located on Tiwai Island and the smaller surrounding islands. All traps were closed permanently on 2 June 2012.

RESULTS

Bait Trials

During field season 1, cameras were set at 44 bait stations for 779 trap nights from February 2009 to June 2009. Pygmy hippos were detected on these camera traps on 22 occasions (2.8 visits per 100 trap nights). However, pygmy hippos consumed bait only infrequently; okra on two occasions, bananas twice and pumpkin once. Bananas attracted a higher frequency of visits by primates, who consumed bait entirely within 24 hours of placement.

In field season 2, cameras were employed at 25 bait stations for 641 trap nights from May 2010 to July 2011. Pygmy hippo photos were captured on cameras on 20 occasions (3.1 visits per 100 trap nights). Nine videos were captured at salt licks, five at sweet potato fields, two at banana, and four at pygmy hippo feces. Two out of eight established salt licks were visited. One female pygmy hippo could be individually identified because her eye did not glow in infrared flash, visited one salt lick on eight occasions for an average of 24.1 (\pm 19) min per visit during 106 trap nights (Figure 5.3). On her last visit, she was accompanied by a calf. One male and one female pygmy hippoptamus visited a sweet potato field on five occasions during 24 trap nights. Although palm nuts repeatedly attracted primates, no pygmy hippos visited these stations.

Pitfall Traps

One trial period, three capture periods, and two closed trap periods occurred from August 2010 to May 2012 with 3121 total trap nights (Table 5.1). During the trial period, nine pitfall

traps were employed for 199 trap nights, and sign was observed on four occasions (2.0 visits per 100 trap nights). Pygmy hippos visited the trap after an average of 9.3 nights post-construction. Due to heavy rainfall and the subsequent drowning of a juvenile red river hog on 22 August in one of the traps, traps were modified with dirt steps to allow animals to exit freely in case of flooding from rain. Steps were removed on 28 September 2010 when precipitation decreased. On 30 September, four juvenile red river hogs fell into a trap and were released without injury. On 21 October, during the trial capture period, a male pygmy hippo was captured in a pitfall trap on the mainland near an agricultural field approximately 100 m from the river. The pygmy hippo was estimated at 200 kg and had a curved scar on the right side of the dorsum. Superficial skin abrasions were observed on the body. Signs on one side of the trap indicated the hippo had attempted to climb out. Two soil-filled rice bags were placed into the trap as a step and the hippo exited within 5 min and fled towards the Moa River (Figure 5.4).

During capture period 1 in January 2011, pygmy hippo sign was observed within 20 m of pit traps on eight occasions at six traps over 235 trap nights: one trap on a small island, two traps > 100 m from the river, and three traps < 50 m from the river. Sign indicated pygmy hippos fell partially in and climbed out of separate traps on three occasions (3.4 visits per 100 trap nights). An average of 8.1 nights passed after trap construction before pygmy hippo sign was observed at any trap. During this capture period, modifications were made to pit traps including weakening the rattan palm mat and blocking alternate trails with wooden stakes to divert hippos into traps.

During 12 February-11 April 2011, traps were closed and monitored, and pygmy hippo sign was observed at 16 of the 20 traps. At these 16 traps, sign was observed on 39 occasions during 1006 trap nights (3.9 visits / 100 nights). Traps located on the Tiwai Island shoreline and the smaller surrounding islands were visited most frequently by pygmy hippos, with

approximately 10.3 events per 100 nights. It took an average of 7.5 nights for a pygmy hippopotamus to visit these traps. On 12 April 2011, traps were reopened for capture period 2 for 360 trap nights. An average of 9.5 nights passed after trap construction before a pygmy hippo returned to the area, and pygmy hippo sign was observed on six occasions at four different traps (1.8 visits / 100 nights). One near-capture occurred when a hippo fell inside the trap but was able to escape, which was determined by footprints around and inside the trap. Half of the six events occurred on the smaller surrounding islands. Modifications made to traps during this period included blocking off alternative pathways to divert pygmy hippos to traps and adding salt licks to entice hippos to the trap.

In April 2012, 23 traps were constructed, but not opened, and monitored for sign for 766 trap nights. Pygmy hippos visited 17 of these traps on 43 occasions (5.6 visits / 100 trap nights). Traps near the river on the northeastern side of Tiwai Island were most frequently visited (58.1% of total events) followed by the smaller islands (27.9%). Traps farther than 50 m from the river were visited six times. An average 13 nights passed before pygmy hippos visited the traps post-construction.

For capture period 3, in May 2012, twenty-one traps of the original 23 built in April 2012 were opened for 555 trap nights. Two traps could not be opened due to water content, and an additional trap near the river was closed after 12 trap nights due to rising river levels. An average 5.8 nights passed before pygmy hippos returned to the area after traps were opened. Pygmy hippos visited nine traps on 18 occasions (3.2 visits per 100 nights); however, very few of these occasions occurred on river islands (16.7% of total events) and no visits occurred at traps > 20 m from the river. Pitfall traps with salt licks had fewer visitations by pygmy hippos (average 1.4 visits without salt per trap versus 0.5 visits per traps with salt). On seven occasions, pygmy hippo

tracks were viewed approaching the trap and stepped on the first portion of the mat, but did not fall inside. During one trap night, a pygmy hippo defecated on two traps and bypassed them. Another near-capture incident occurred when the field team was repairing a trap damaged by heavy rainfall. Two field assistants encountered a pygmy hippo, which fled to the river < 50 m from the trap. Modifications to traps during this time included adding two to three solid crossbars to each side, weakening the middle supportive cross-sticks, weakening the mat, and blocking alternative pathways with wooden stakes to divert hippos towards the traps.

DISCUSSION

Our study evaluated the use of pitfall traps for physical capture of a pygmy hippo in Sierra Leone. Although we failed to attach a radio transmitter to a pygmy hippo, we successfully captured and released a male pygmy hippo using pitfall traps. We believe the results of our research can be used to guide future capture attempts. Pitfall traps are logistically easy to construct and can be modified to lessen animal welfare concerns.

Capture periods lasted from 235 - 555 trap nights (total 1,349 trap nights), and we had one successful capture and five occasions where hippos fell into the trap and escaped. If trap failure had not occurred, we would have captured one pygmy hippo approximately every 225 trap-nights. Furthermore, our study revealed a higher frequency of visits near the traps < 50 m from the Moa River. Therefore, increasing trap nights and number of traps as well as placing traps near access points on rivers should improve capture probability.

While our study suggests pitfall traps may be the safest and most efficient method to capture pygmy hippos, these traps possess a number of limitations that should be carefully considered before application. Possible disadvantages include the possibility for traumatic injuries, the possibility of capturing > 1 animal at a time (e.g. a female with a calf), the labor

involved in building multiple traps, the capture of non-target species (including people) and the limited space for safe manipulation inside the trap once the animal is anesthetized. However, we feel in Sierra Leone the overall advantages outweigh these risks. Visual observations are rare and pygmy hippos may not use the same trails on consecutive nights. Therefore, multiple traps need to be constructed to increase the probability of capture. Once contained in a trap, animals generally remain calm, making it easier to estimate the body weight to calculate and administer precise anesthetic drug quantities (Hernandez-Divers et al. 2007). Post-anesthesia release is also safer, as the animal can walk out of the collapsed trap only after it has fully recovered. We decreased the likelihood of injury by placing bags filled with dried grass and leaves on the bottom of the trap to cushion impact. The pygmy hippo we trapped appeared calm and only became agitated when we began manipulating the trap to add bags for steps. This animal had only superficial skin abrasions, and descriptions from Van den Brink (1964), Schomburgk (1912) and Hentschel (1990) of pygmy hippos and reports of other large mammals do not report any capture-related injuries (Medici 2010).

Our research on Tiwai Island explored attractants for pygmy hippos to increase capture probability, and some of our bait stations were moderately successful. However, bait availability was logistically difficult, as many fruits were only available seasonally and spoiled rapidly. Furthermore, local people did not have excess food to spare for sale and the remoteness of the study site created difficulties in replenishing stocks. While sweet potato leaves attracted hippos, it is only grown seasonally near water sources and the proximity of most sweet potato fields to the river not ideal. Salt was the only bait resulting in repeated visits. Salt has the advantage of ease of transport and storage without spoiling. Concerns arose with building traps on agricultural land easily accessible to the public. The trial period capture near an agricultural field attracted

human bystanders from the nearby village even after we requested people to avoid the area due to concerns about stress or injury upon release from the increased noise and activity in the area. We were also concerned about people inadvertently falling into traps and being injured. Therefore, we were limited to building traps on islands away from the mainland to limit access to the locations.

Multiple misses of pygmy hippos during our study were often caused by trap failure and environmental issues, which we attempted to correct through various modifications. One significant problem during the first two capture periods was the pitfall trap depth (1.5 m). Medici (2010) found any trap shallower than 2.0 m allowed tapirs to escape, and the same appeared to be true for pygmy hippos. Therefore, we deepened the traps to 1.8-2.0 m for capture period 3. As pygmy hippos sometimes diverted around the trap or chose another path, we attempted to funnel pygmy hippos using wooden poles to block alternative pathways. This was especially problematic in capture period 3 with traps near the river when we attempted to block off alternative access points to the river; however, pygmy hippos were able to continue forging new exits and entrances.

Another concern both for our study and for Hentschel (1990) in Côte d'Ivoire was the ability of pygmy hippos to detect disturbance to an area by humans. As evidenced by video and tracks, pygmy hippos appeared to be able to detect the traps before stepping on them, resulting in backing up or completely bypassing the area. Furthermore, camera traps placed during capture period 1 may have altered the trajectory of pygmy hippos as they may have detected the camera sound or saw the infrared flash. In one case, a pygmy hippo was observed on video stepping on the edge of a trap, backing up and running perpendicular to the trap. Another video revealed a hippo turning around and running away. On three occasions, a field assistant encountered a

pygmy hippo near a trap, which caused the pygmy hippo to flee. During one trap night, a pygmy hippo defecated on two nearby traps, lending support to our suspicion pygmy hippos were aware of the traps. To reduce some of these issues, we removed the cameras from the area after the first capture period and attempted to minimize disturbance around the traps. Because hippos may be able to smell freshly dug soil, we transported soil from excavated traps > 50 m from the traps, minimized the cutting of trees and shrubs, and gathered camouflaging forest debris > 30 m from traps.

To allow hippos to re-acclimate to an area after trap construction, we excavated traps and covered them with strong sticks so animals would not break-through but we could monitor for sign. In the trial period and capture periods 1 and 2, approximately one week passed before pygmy hippos returned to an area after traps were built. In capture period 3, approximately 5.8 days passed before hippos visited the area; therefore, building traps before the capture period may decrease the time for hippos to visit the traps when they are opened. An adjustment period should be taken into account, although some of the traps were visited on the first night.

Environmental factors also posed some limitations. The rainy season was an obstacle in both the trial period and the third capture period. On several occasions, mats became saturated with rain and collapsed. Three of the traps became unusable in capture period 3 because of rising water levels. Rainy season also increased the risk of traps filling with water, which can lead to drowning. Alternatively, at the end of the dry season, traps became difficult to dig because of the dry, compacted soil. The optimal time for pitfall traps in Sierra Leone is likely between October and March. We experienced the highest trap success in the dry season from February to April and our successful capture occurred in late October. Anecdotal accounts by local residents indicate pygmy hippo movement may change between the dry and rainy seasons because of

water depth. Capture period 3 occurred at the cusp of rainy season, and it is possible the difference in visitation rates on the islands before and after the opening of the traps signified a change in these movements. We strongly caution against the use of pitfall traps during rainy season.

Trap failure in capture period 3 was caused by supportive cross-sticks not breaking completely or mats being woven too tightly to break immediately, allowing the pygmy hippo to back out of the trap. We weakened the mats and the cross-sticks, but were unsuccessful in capturing another hippo.

We believe with more time, researchers can safely capture pygmy hippos using pitfall traps for the application of radio collars and other procedures. Capture and radio tracking of pygmy hippos will be essential to devising a comprehensive conservation plan for this elusive and endangered species that includes accurate details on the habitat requirements, home range size and movements.

While we considered pitfall traps the most suitable capture method, we originally explored alternative capture techniques. Darting from platforms is a common approach for tapirs and other large mammals (Foerster and Vaughan 2002). However, during a preliminary platform trial, 92 observation nights yielded no pygmy hippo encounters. Visual observations of pygmy hippos are rare and their movements difficult to predict, as evidenced by our camera traps. Darting hippos from platforms requires they are attracted by and return to bait on a regular basis; however, during our study we were unable to identify specific bait that would consistently attract hippos, although salt had preliminary success. Dart platforms require clearing a large area of ground and mid-story vegetation to improve visibility, but this inherently increases disturbance and likely decreases visitation of hippos to the area. Long waiting periods are required and since

pygmy hippos are nocturnal, accurate estimation of body weight and precision of the shot is limited. Furthermore, inherent dangers exist when attempting to dart an unconfined animal. For instance, when startled, pygmy hippos tend to run towards the nearest water source (Eltringham 1999). Like the common hippopotamus, darting a pygmy hippo near water may result in death by drowning if the hippo entered the water while anesthetized (West et al. 2008). Another disadvantage is the possibility an anesthetized pygmy hippo could run far into dense vegetation prior to anesthetic effect, making both location of the individual and manipulation once found difficult. Therefore, darting a physically unrestrained pygmy hippo is neither the safest nor the most efficient method.

Box traps are another method used to capture ungulates, including tapirs (Medici 2010) and Spanish ibex *Capra pyrenaica* (Casas-Díaz et al. 2008). However, species like tapirs are often reluctant to enter a box, even with bait as an attractant (Hernandez-Divers et al. 2007). As we found, pygmy hippos in this region are very sensitive to disturbances and we are doubtful one would voluntarily enter a box trap. Furthermore, box traps made of materials sturdy enough to contain a fully-grown pygmy hippo are logistically difficult to transport and assemble in remote locations. Ideally, traps would also need to be large enough for a field team to maneuver during procedures inside the trap, because moving an animal of this size and weight once anesthetized is problematic. However, if the box is too large, a pygmy hippo may fight to escape to the point of either exhaustion or injury. Haulton et al. (2001) compared four capture methods and found box traps caused the highest frequency of injuries for white-tailed deer *Odocoileus virginianus*. While it may be possible to capture a hippo in a box trap animals are likely to avoid them, they are logistically difficult to construct, and they pose significant welfare concerns.

Hunting dogs have been used to capture mountain tapirs *Tapirus pinchaque* in Colombia (Lizcano and Cavelier 2004); however, when hunters were questioned in Sierra Leone, they unanimously agreed dogs would not approach a pygmy hippo (A. Conway, unpublished data). Furthermore, the geographical terrain of Tiwai Island is unsuitable; pygmy hippos can escape into the river, making dogs ineffective. If trained dogs were available, they may injure the pygmy hippo as they have with tapirs (Hernandez-Divers et al. 2007). The use of hunting dogs is therefore inadvisable for this species.

Bomas generally work well for species living in an open landscape where large sturdy structures can be constructed in anticipation of captures weeks in advance. Common hippopotamus bomas are built weeks in advance, and animals become accustomed to feeding inside the boma until the trap is sprung (McKenzie 1993). Despite this success with similar-sized species, dense closed-canopy tropical landscapes are not conducive for building bomas because of the logistical difficulty of transporting materials sturdy enough to contain pygmy hippos, the lack of open space in which to build, and the elusive and sensitive nature of these species. Indeed, the remoteness and geographic composition of our study site make bomas unfeasible.

While leg hold snares have been used on felid species like pumas *Puma concolor* (Logan et al. 1999) and some African ungulates (Mossman et al. 1963), snares can produce significant injuries and potential mortality. Hunters near our study site described occasions when they had captured pygmy hippos in snares; they would attempt to escape until near exhaustion and death and debilitating leg injuries were common (A. Conway, unpublished data). Attempts to modify snare traps for safety in Côte d'Ivoire resulted in escape (Hentschel 1990).

Key Recommendations

- Salt may be the best attractant to entice pygmy hippos to traps as other baits we attempted mainly attracted other species, were difficult to replenish and did not result in repeated visits by pygmy hippos
- Pitfall traps should be a minimum of 1.8 m and preferably 2.0 m in depth
- Pitfall traps should be constructed, but not activated to allow re-acclimation to an area before capture periods begin. Bait should be used at this time and traps should be monitored for sign
- Modifications to increase capture probability include funneling pygmy hippos toward the trap including barricades made of sticks or logs, weakening the notched cross-sticks and supportive mat, and adding bait to the trap
- Traps may have a higher probability of capture if they are placed near river entrance and exit points frequently used by pygmy hippos
- We strongly advise capture periods to be conducted in the dry season
- We recommend a 3-month consecutive capture period with 20 traps minimum
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Table 5.1. Time periods, total number of traps and trap nights for pitfall traps constructed for physical capture of pygmy hippopotamus *Choeropsis liberiensis* on and around Tiwai Island Wildlife Sanctuary, Sierra Leone

Period	Time Period	Season	# Traps	# Trap	Total #
			I	Nights	Events
Trial	08/18/2010 - 10/22/2010	Late Wet	9	199	4
Capture 1	01/16/2011 - 02/03/2011	Early dry	14	235	8
Closed and monitored	02/12/2011 - 04/11/2011	Mid dry	20	1006	39
Capture 2	04/12/2011 - 04/28/2011	Late dry	20	360	7
Closed and monitored	04/24/2012 - 05/05/2012	Late dry	23	766	43
Capture 3	05/04/2012 - 06/01/2012	Early wet	21	555	18



Figure 5.1. Map of Tiwai Island Wildlife Sanctuary and surrounding area in southeastern Sierra Leone, displaying locations of pitfall traps in Trial Period (n = 9, August – October 2010), Capture Period 1 (n = 14, January 2011), Capture Period 2 (n = 20, April 2011), and Capture Period 3 (n = 21, May 2012) for physical capture of the pygmy hippopotamus *Choeropsis liberiensis*.



a.



Figure 5.2. a) Pitfall trap showing grass-filled bags and supportive sticks to physically capture a pygmy hippopotamus *Choeropsis liberiensis* excavated with dimensions 2.0 m X 1.0 m X 1.5 m on Tiwai Island Wildlife Sanctuary, Sierra Leone. b) Woven rattan palm mat with forest debris.



Figure 5.3. Still shot photograph taken by a camera trap of a female pygmy hippopotamus *Choeropsis liberiensis* at a salt lick on Tiwai Island Wildlife Sanctuary, Sierra Leone



Figure 5.4. Male pygmy hippopotamus *Choeropsis liberiensis* captured in a pitfall trap near Tiwai Island Wildlife Sanctuary, Sierra Leone

CHAPTER 6

OCCUPANCY AND ACTIVITY PATTERNS OF THE PYGMY HIPPOPOTAMUS *CHOEROPSIS LIBERIENSIS* ON AND AROUND TIWAI ISLAND WILDLIFE SANCTUARY, SIERRA LEONE¹

¹Conway, A.L, Carroll, J.P., and Sonia M. Hernandez. To be submitted to *Journal of Tropical Ecology*

ABSTRACT

The Upper Guinea rainforests of West Africa are a global hotspot for biodiversity and endemism. The pygmy hippopotamus *Choeropsis liberiensis*, is an endangered and rare species endemic to these forests. Camera trapping is an increasingly popular method to survey cryptic species, and results can be used for occupancy analyses and activity pattern evaluation. The objectives of our study were to 1) obtain estimates of occupancy and detection probability of ungulates, specifically the pygmy hippo, in a protected area 3) identify habitat characteristics influencing pygmy hippo occurrence on and around Tiwai Island, Sierra Leone and 3) describe activity patterns of pygmy hippos. We detected pygmy hippos among 24 mammal and 11 avian species, with sooty mangabeys the most often detected. We found pygmy hippos had a higher probability of occupancy in riparian and swamp habitats on Tiwai Island and on the smaller unprotected surrounding islands. Furthermore, occupancy rates decreased farther from the Moa River. Pygmy hippos were mainly nocturnal and had activity peaks from 20:00-22:00 and 01:00-03:00. They appeared to be more active during dry season. Although we had low detection, this study demonstrates the utility of camera trap surveys for a rare species like the pygmy hippopotamus.

INTRODUCTION

Tropical rainforests house more than half of the global species, yet they only cover approximately 7% of the land area and are some of the most rapidly declining ecosystems (Myers 1993, Laurance 1999). The Upper Guinea rainforests of West Africa in particular have a high degree of species richness and endemism, yet are poorly understood in terms of ecological functions (Norris et al. 2010). These forests are highly threatened by anthropogenic forces and are therefore designated a global hotspot for biodiversity conservation (Mittermeier et al. 1998).

Like most areas of high biodiversity, these forests are vulnerable to human conflict (Hanson et al. 2009) and are located in countries where poverty is widespread (Fisher and Christopher 2007).

Ungulate species are some of the most highly exploited species in the Upper Guinea rainforests. However, the ecology of many ungulate species is poorly described, often due to their rarity and elusive behaviors (Bowkett et al. 2006). Many of these species provide ecosystem services important to human livelihoods and ecosystem health as a whole. For example, ungulate species, like duikers in Ghana, influence forest structure by acting as seed dispersers and nutrient recyclers (Hofmann and Roth 2003), They are also important prey for large predators (Redford 1992). Hunters in the tropics often target ungulate species for both subsistence and commercial purposes (Barnes 2002, Fa et al. 2005). While many species of ungulates (i.e. duikers) reproduce rapidly and are capable of withstanding a degree of hunting pressure, larger-bodied and slowerreproducing species are especially prone to extinction (Brashares et al. 2001, Bennett et al. 2007).

The pygmy hippopotamus (*Choeropsis liberiensis*) is an endangered ungulate species endemic to the Upper Guinea rainforests of West Africa. Very little is known about pygmy hippo biology and ecology due to their elusive and semi-aquatic lifestyle, as well as their rarity and scattered distribution over a broad scale (Mallon et al. 2011). Although they appear to be less dependent on water availability than their relative, the common hippopotamus *Hippopotamus amphibious*, pygmy hippos are thought to mainly inhabit primary rain forest near water sources and in raphia swamps (Robinson 1970, Bülow 1987). Major threats to pygmy hippo survival include poaching for meat and deforestation from slash-and-burn agriculture, expansion of commercial plantations, and logging (Mallon et al. 2011). Approximately 80% of the original

forests in West Africa has been lost in the last century and now exists primarily as an agricultural-forest mosaic (Norris et al. 2010). Furthermore, protected areas may not offer adequate protection for pygmy hippos, either because of weak enforcement or lack of financial and technical resources (Mallon et al. 2011). Civil conflict has also hindered conservation projects and protection of reserves over the past 20 years in West Africa (Lindsell et al. 2011). Advanced knowledge is urgently needed to understand pygmy hippo distribution, habitat use, behaviour, and threats to conservation status.

Pygmy hippos are some of the most elusive mammals on the African continent (Robinson 2003), and traditional survey methods may not be adequate for surveying their populations. Indirect techniques like line transects surveys of sign have been used to obtain relative indices of population declines (Hoppe-Dominik et al. 2011, Vogt 2011). Radio telemetry is another method which Bülow (1987) used to study translocated pygmy hippos in Cote d'Ivoire. While radio telemetry can provide information on home range size and resource use, the method is often labor and cost intensive in tropical settings. Furthermore, telemetry attachment requires physical capture of a species (Kenward 2001), and pygmy hippos are notoriously difficult to immobilize and anesthetize (Miller 2007). Physical capture of a large mammal in itself can be dangerous for both researchers and the species involved.

The recent development of commercial game cameras for use in scientific research may provide a closer, more comprehensive assessment of pygmy hippo populations. Camera trap surveys require minimal labor and training input and are feasible in a variety of environmental conditions (Swann et al. 2004). Because cameras can remain in place inconspicuously for long periods of time, camera traps are often employed in capture-mark-recapture studies to estimate abundance on cryptic or disturbance-sensitive species like snow leopards *Panthera uncia*

(Jackson et al. 2006) and tigers *Panthera tigris* (Karanth 1995). Camera trapping has gained popularity as a method to record the presence of rare species as well as estimate occurrence, activity patterns, species richness and demographic parameters (Claridge et al. 2005, O'Connell et al. 2006). Recent camera trap surveys have collected presence/absence data for ungulates to determine the influence of habitat in Tanzania (Bowkett et al. 2007) and community-based conservation in Peru (Licona et al. 2011). Repeated surveys allow for occupancy modeling which incorporates imperfect detection probabilities to address questions related to resource selection, distribution, and geographic range (O'Connell et al. 2011). This method is especially relevant when animals cannot be individually identified or captured (MacKenzie 2005).

In addition to occupancy and abundance estimation, camera trap data can be used to examine the activity patterns of mammals (Lucherini et al. 2009, Jiménez et al. 2010). Remote camera systems are less likely to disturb and affect behavior of an individual than direct observations (O'Connell et al. 2011). Data obtained from these traps have allowed conservation practitioners to quantify circadian rhythms of François' langurs *Trachypithecus francoisi* (Zhou et al. 2007), niche partitioning between jaguar *Panthera onca* and puma *Puma concolor* in Bolivia (Romero-Muñoz et al. 2010) and habitat use of ocelots *Leopardus pardalis* (di Bitetti et al. 2006). Camera trap monitoring is developing as a method used for pygmy hippos (Collen et al. 2011), although neither occupancy nor activity pattern analyses from camera traps have been conducted.

The objectives of this study were to 1) obtain estimates of occupancy and detection probability of pygmy hippo in a protected area, 2) identify habitat characteristics influencing pygmy hippo occurrence on and around a protected area and 3) describe the activity patterns of

pygmy hippos. We predicted pygmy hippos to have a higher probability of occupancy in swamps and riverine habitats and that they will be primarily diurnal based on results by Bülow (1987).

STUDY AREA

Tiwai Island Wildlife Sanctuary (07°33'N 11°19'W) is part of the Upper Guinea Rainforest and is located in southeastern Sierra Leone on the Moa River (Figure 6.1). The island, adjacent to the western end of Gola Rainforest National Park, rises to an elevation of approximately 110 m above sea level with an area of 1150 hectares (approximately 12 km²). The coastal plains cover an area to the south reaching 65 km to the outlet of the Moa River into the Atlantic Ocean. The nearby Kambui Hills Reserves are comprised of two major blocks, North (20,348 ha) and South (880 ha), and the southern end reaches to within 4 km of Tiwai Island. Sierra Leone has a dry season lasts approximately from December to March and a rainy season from May to October. April and November are transitional periods. Rainfall is approximately 3000 mm per year, with most precipitation falling between July and September (Oates et al. 1990b).

Vegetation on Tiwai Island is a mixture of bush fallow, palm swamps, and old secondary forest. *Raphia*-palm swamps and riparian forest cover about 10% of the island, and regenerating forest from old farm settlements and windfalls comprises 30% (Oates et al. 1990b). Tree species in old secondary deciduous growth include *Piptadeniastrum africanum*, *Cynometra leonensis*, *Funtunmia africana*, and *Parinari excels* (Fimbel 1994). The central portion of Tiwai Island contains a grid system, with transects cut into the understory located at 50 m intervals along N-S and E-W compass bearings (Whitesides et al. 1988).

Lower Tiwai is a 13.6-km² island 2 km south of Tiwai Island Wildlife Sanctuary. Comprised of about 60% old secondary forest, Lower Tiwai is similar in vegetation composition

to Tiwai Island (White 1986). Lower Tiwai is currently unprotected in any official capacity; however, there are no long-term human settlements on the island, except for seasonal farming. Hunters and fishermen use a network of pathways throughout the island.

The surrounding mainland is as a mosaic of villages with upland bush fallow comprised of *Musanga cecropioides*, *Harunqana madagascariensis* and *Sceleria barteri*, and secondary forests with small-scale coffee and kola nuts plantations interspersed. African rice *Oryza glaberrima* is grown in both lowland and upland swamps, and cassava, groundnut and maize are used for supplementary food and income (Davies and Richards 1991).

METHODS

We used two types of commercially available heat- and motion-sensing, infrared, digital cameras (Moultrie Game Spy I40, Moultrie Feeders, Alabaster, USA; and Bushnell Trophy Cam, Bushnell Corp., Overland Park, KS, USA) to detect terrestrial mammals on and around Tiwai Island Wildlife Sanctuary. The island was divided into 1 km × 1 km blocks within a Geographic Information System (ArcGIS 9.3, ESRI, Redlands, CA). All blocks were considered potential sampling units, and one infrared-triggered camera was set in each sampled block in a random location. Random points were also generated for the 14 islands owned by a local village, and five of these islands were randomly chosen for placement of Bushnell cameras. All cameras were placed within 50 m of the random point based on tree availability and were attached to trees at approximately 0.6-0.8 m height.

Camera trap surveys on Tiwai Island were conducted in four periods from October 2008 to February 2009 (field season 1) and over six periods from May 2010 to July 2011 (field season 2). During the first field season (2008-2009), cameras were deployed at each site for approximately 14 days, then collected for maintenance and moved to another random location

within the 1 km² block for the next period. During the second field season (2010-2011), cameras were deployed for 21 days. In field season two, cameras were deployed on Lower Tiwai for two periods for 21 days each.

All cameras were set to operate 24 hrs per day and take two consecutive pictures (with a 10-second delay) upon detection of an animal. Time and date were automatically recorded on each photograph except during camera malfunction or technical errors. The sampling effort at each location (number of camera-nights) was the time between camera deployment and collection. If the camera did not trigger when field staff activated the sensor at the time of collection, the date of the last photograph was used as the last known day of operation. To avoid double counting the same individual, a trap event was defined as an animal captured more than 0.5 hrs apart similar to O'Brien et al. (2003). If the same species was captured more than once within a 0.5 hrs interval, and the animal could not be individually identified, it was considered the same trap event.

At each location, Universal Transverse Mercator (UTM) coordinates were recorded with a Global Positioning System (GPS). General habitat type, presence of human or animal trails, and understory density were recorded. Distance from the camera to the Moa River, nearest stream, swamp and human transects were calculated through spatial analysis using ArcGIS 10. *Occupancy Modeling and Analysis*

Individual identification of hippos is difficult because of their lack of markings and ability of scars to rapidly heal (Hashimoto et al. 2007), and therefore we could not use capturemark-recapture methods for this species, and raw count data is a poor index for abundance (Boitani and Fuller 2000). To account for detection probabilities < 1.0, we used occupancy modeling to estimate site occupancy rate (ψ) of terrestrial mammals based on repeated

presence/absence surveys on camera traps (MacKenzie 2005). Encounter histories were managed in a Microsoft Excel database and we used models developed by MacKenzie et al. (2002). We constructed a sampling history by each site and species. Our periods were pooled into two (field season 1) or three (field season 2) 7-day sampling segments (days 1-7 = first trapping occasion, days 7-14 = second trapping occasion) to reduce excess zeros, similar to Karanth et al. (2011).

We used occupancy analysis to assess the effect of covariates, including habitat type, understory density, distance to river, presence of a trail, and location of the camera (Table 6.1). Occupancy analysis was conducted using program MARK (White and Burnham 1999) and involved six covariates for occupancy, two detection variables, as well as time. We modeled occupancy and detection as constant across sites and samples [$\psi(.)p(.)$] and modeled occupancy as a function of covariate types. We compared 12 candidate models (including a null model) using Akaike's Information Criterion, corrected for small sample size (AIC_e) and ranked models according to AIC weight (*w*) (Burnham and Anderson 2002). We examined average site occupancy rates and detection probabilities of pygmy hippos based on the top occupancy models. Single season occupancy modeling assumed a closed population over the survey period, and independence between sampling points.

Activity Patterns

The date, time, and lunar phase from our camera traps were used to characterize activity patterns of pygmy hippos on and around Tiwai Island Wildlife Sanctuary. Cameras placed along areas where pygmy hippo sign was observed (i.e. footprints, dung, feeding sites, and visual observations) were used to supplement information from the random cameras. Monthly activity patterns were calculated by number of photo events per 100 trap nights. The sunrise in the region occurs between 06:33-7:07 throughout the year and the sunset ranges from 18:29-19:15. We

defined nocturnal activity to be between 20:00 and 06:00. Time periods were pooled into 1 hr intervals, and level of the activity was measured by the proportion of total photographs within this interval. We calculated number of photo events per month to examine seasonal variability. Months were pooled across years 2009, 2010 and 2011. We then explored differences in frequency of photographs using χ^2 tests of independence.

RESULTS

During 2008-2011, cameras were deployed for 3,219 trap nights, resulting in 1,973 photographs of mammals and birds (998 independent events) from 5,644 total photos. The remaining photos with no animals due to camera malfunction or environmental variables (e.g. rain, wind, animals moving out of frame before capture) were discarded. A total 184 locations were sampled during ten periods on Tiwai Island and two periods on Lower Tiwai Island. Camera traps were spaced at an average of 714 m (\pm 237) apart ranging with a range of 440.3-887.6 m. Our overall trap success was 31.0 photo events per 100 trap-nights. Although our original design was two to three-week sampling at each location, the sampling duration fluctuated between two days and four weeks because of logistics, camera failure or weather issues. Photographs taken beyond the two or three week time periods were excluded from analysis.

Including pygmy hippos, 24 mammal species (including eight species of primates, eight species of ungulates, five carnivore and two rodent species) were detected during the surveys (Table 6.2). Fifty photographs could not be identified beyond 'mammal' or 'bird' due to poor focus or lighting. Upper Tiwai and Lower Tiwai had similar composition of mammal and avian species.

Due to low detection rates of pygmy hippos, I combined trap-nights and field seasons. Pygmy hippos were detected on 35 occasions at 30 locations for 3.5% of photo events. Combined field seasons had a naïve occupancy rate of $\psi = 0.16$. Twelve models were evaluated to determine best fit for our data. When field season 2 was evaluated alone, no models were ranked higher than the null model $[\psi(.)p(.)]$. For the combined field seasons, the most likely model included occupancy as a function of vegetation with a constant detection probability $[\psi(\text{Veg})p(.)]$ (Table 6.3). Covariate coefficients for models all included 0 in the 95% confidence intervals, and all models were $< 7 \Delta AIC_c$, indicating there was not strong support for the best model and parameter estimate uncertainty was high (Table 6.4). However, models incorporating occupancy as a function of location of the camera (w = 0.36) and vegetation (w = 0.18) ranked among the highest and were the only models ranking higher than the null model ($\leq 2.0 \Delta AIC_c$). Pygmy hippos appeared to prefer riparian and raphia swamp habitats over forested areas, with the highest occupancy rate in riparian areas ($\psi = 0.82$ SE = 0.35; Table 6.5). The smaller islands surrounding Tiwai Island had a higher occupancy rate ($\psi = 0.87$, SE = 0.42). Detection probabilities across constant models were p = 0.21. Time appeared to influence detection as it was ranked as a top model $[\psi(\text{Veg})p(t)]$, with detection probabilities decreasing from 0.24 to 0.11 from the first to third sampling period. The model average for occupancy was 0.36 (SE = 0.17). However, of our models, camera location on human versus animal trails appeared to have no effect on either occupancy or detection. There also appeared to be no seasonal variation in probability of occurrence. Vegetation density influenced neither detection nor occupancy. Although distance to the Moa River was not one of the highest ranked models ($\Delta AIC_c 5.14$), a plot of occupancy as a function of distance indicated a negative relationship (Figure 6.2). The

probability of occupancy ranged from 0.41 at the riverside to 0.24 farther than 1000 m from the river.

Lower Tiwai Island was sampled in the dry season for two periods of 21 days and had a slightly higher occupancy rate than Tiwai Island ($\psi = 0.18$); however, low numbers of sample sites and hippo detections did not permit occupancy modeling on this island. However, a notable discovery was a photograph taken of a female with her calf near the river. The site appeared to be an access point for hippos, as a hippo visited the camera on five occasions over the course of two weeks.

Activity Patterns

With the addition of the supplementary cameras, pygmy hippos were observed on 95 occasions over 4475 trap nights at 62 camera trap locations on both Tiwai Island Wildlife Sanctuary (Figure 6.3) and Lower Tiwai Island (Figure 6.4). Most observations occurred in swamps or in riverine habitats near the shoreline. Generally, the areas near the smaller islands on the western side of Tiwai Island had the highest detection. Pygmy hippos were also observed on six of the smaller islands near Tiwai Island. Only three cameras on the southern 2 km of Tiwai Island detected any pygmy hippos. Pygmy hippos were detected on three cameras on Lower Tiwai Island, and two of these were near the river. Overall, there were an average 1.8 events per 100 trap nights (Figure 6.5). Analysis of data from March-June displayed a peak activity in May, with approximately 30% of all photographs taken during this month and approximately 60% of all photographs collected in this season. The sampling period of July-November during the rainy season detected few pygmy hippo events, with ≤ 1 trap event per 100 nights.

Pygmy hippos were mainly recorded at night, with 25 (61.0%) events between 20:00 and 6:00 (Figure 6.6). Peak activities periods occurred between 20:00-22:00 and 01:00-03:00 with a

smaller peak between 06:00 and 08:00. Four photographs were taken in daytime hours between 09:00 and 17:00 and these photographs were all collected in the rainy season (Figure 6.7). While there was no significant difference in activity between seasons, pygmy hippos tended to be active later in the morning during wet season, with 8.2% of photographs taken between 09:00 and 11:00. No photographs were taken of a pygmy hippopotamus after 09:00 in dry season. There was also a lower event per trap night rate in the wet season, at 1.6, versus 2.0 events per trap night in the dry season. The lunar cycle did not appear to significantly affect activity levels of pygmy hippos, as they were active during all lunar periods equally, although they appeared to be more crepuscular in activity when the lunar cycle was near full (Figure 6.8). During the full moons, there were sharp increases in activity at 21:00 and 7:00, whereas during the new moon activity peaks happened from 18:00 to 21:00 and smaller peaks throughout the night. During both full and new moon, activities were similar between 24:00 and 04:00.

While we could not identify pygmy hippos consistently, we were able to detect the sex of individuals during 14 (35%) events. Males were identified based on presence of penis curling caudally (Steck 2008). Three of four females were identified based on presence of young at their side. Females were identified based on presence of an udder. The remaining detections were males. Female and calf pairs were observed on five cameras during 2009 to 2011, including one on Lower Tiwai Island. Calf pairs were observed at all times of the year and appeared to be < 1 year old, as they were about half the size of the mother. Males and females utilized the same areas on several occasions. At one camera near the river on Tiwai Island, a female and offspring were observed, and 29 hrs later, a male hippo visited the same location. At another location, a female visited an agricultural field to feed and on a male visited the same area 54 days later.

DISCUSSION

Occupancy

Large mammals are especially vulnerable to anthropogenic factors, including deforestation and hunting, and understanding the habitat requirements of these species is important for their conservation. Our study examined the feasibility of using camera traps to shed light on occupancy rates and activity patterns on a little known species, the pygmy hippopotamus, in Sierra Leone. Applying a camera trap method enabled us to collect detection data on a species with little previous ecological knowledge, and also highlighted the importance of buffer areas like the smaller unprotected islands for providing habitat to an endangered species. We were also able to detect pygmy hippos on an unprotected river island with similar, size, vegetation and wildlife composition to Tiwai Island. Furthermore, camera traps allowed us to reveal species previously undocumented on Tiwai Island. These included the previously undocumented bongo, and a species thought to be locally extirpated - the black duiker (Appendix 6.1). On Lower Tiwai, cameras captured a rare photograph of an olive colobus *Procolobus verus* carrying her young inside her mouth.

Precision and modeling capacities were hindered due to small number of traps deployed in each period and detection probabilities of < 0.3. Our confidence intervals indicated a high level of uncertainty. However, our low detection rates were similar to those in other studies of pygmy hippos across their range. For example, during 1,247 camera trap days, Collen et al. (2011) obtained seven pygmy hippo events (0.56 events per 100 trap days) in Sapo National Park, Liberia. A survey by Vogt (2011) in the same protected area found pygmy hippo sign on 26 days out of 151 days; however, a visual and dung sighting occurred only once. In Cote d'Ivoire, Hoppe-Dominik et al. (2011) found declining detection rates by a third between surveys

conducted over three decades. While we were able to identify some of the pygmy hippos in this region based on morphological abnormalities, pygmy hippos generally do not have individual markings, and scars tend to heal quickly (Hashimoto et al. 2007). Therefore, capture-recapture methods are not feasible for this species. Based on our study and results from other studies on cryptic mammals (Claridge et al. 2005, Linkie et al. 2007), we believe camera traps provide a valid method for activity patterns and occupancy analyses. Expansion of surveys on pygmy hippos will require intensive sampling because of their rarity, scattered distribution, and low detection probabilities.

We found an increased probability of occurrence in riparian habitat and swamps, which is consistent with the known natural history of pygmy hippos (Mallon et al. 2011). While the smaller islands had a higher detection, these areas also have a high level of anthropogenic use, including agricultural fields, artisanal diamond mining and palm plantations. In fact, our camera surveys and interviews with local farmers indicate pygmy hippos are using agricultural fields and the smaller community owned islands as feeding sites and resting areas. Pygmy hippos were conspicuously absent from the southwestern part of Tiwai Island, even with similar survey efforts in these areas. The exact basis of this lack of detections is unclear. However, anecdotal evidence indicates hunting pressure exists from poachers in these areas; the research team heard gunshot sounds on multiple occasions and encountered a poacher once, and four cameras were stolen in this area. The main host villages are in the north, and therefore poachers can cross over to the island to the south of these villages relatively easily and unseen. From a habitat standpoint, the river to the western and south part of the island is fast moving, which may cause hippos to avoid crossing in these areas.

Our study only evaluated occupancy as a function of two seasons: wet and dry, and pooled the eight sampling periods into one for purposes of occupancy modeling. Multi-season models could be used to monitor pygmy hippo populations over time if sufficient detections can be obtained (MacKenzie et al. 2003). However, our low detection rate did not allow for multi-season models. Expanding camera surveys over the range and more seasons will allow estimations of local extinction and colonization probabilities. Another method to increase detection rates would be through the use of lures or baits. Although we were unable to find bait that would attract a hippo consistently to one area, we had limited success with salt licks, and one salt station attracted a female hippo on eight occasions over 2 months from 21:08 to 7:25 hrs (A. Conway, Chapter 5). However, more time is needed to determine whether salt could be used to increase detection rates. Furthermore, if *a priori* knowledge of the geography and habitat types is available (e.g. via satellite imagery), stratified sampling should be considered in riparian habitats and swamps.

Activity Patterns

Previous studies used radio telemetry, although with limited sample size, and reported pygmy hippos as active from mid-afternoon until midnight, with a peak activity between 16:00 and 23:00 (Bülow 1987). However, our findings suggest pygmy hippos do not become active until approximately 19:00 and are likely active throughout the night. One of the highest peaks of activity occurred at 02:00, which suggests hippos may be foraging for food through early morning hours. In fact, several cameras placed in agricultural fields on the smaller islands captured pygmy hippos feeding around this time. During the wet season, pygmy hippos also appeared to be active later in the morning and were not active until later in the evening (20:00). Whether this is a reflection on geographical variation or the technique used (radio telemetry

versus camera traps) is unclear and should be investigated further. However, pygmy hippos are thought to be dependent on water sources because of their skin, although not as much as the common hippopotamus *Hippopotamus amphibious* (Eltringham 1999). The availability of water sources in the forest during rainy season may allow them to wallow and bathe within the forest rather than returning to the river.

While we did not observe any difference between the wet and dry seasons in our occupancy analyses, when we supplemented the additional photographs at highly frequented pygmy hippo areas, we found hippos were detected with a higher frequency in the dry season. The higher capture frequency may indicate an increase in movement in search of scarcer resources. Furthermore, it may be useful to focus sampling during the dry season because cameras are less likely to malfunction due to humidity and rainfall. Pygmy hippos appeared to be more crepuscular during nights near the full moon, although this was not a significant affect. Moonlight may have little effect when the canopy is dense and therefore little light penetrates into the forest. Additional camera trap effort may yield answers on seasonal variations of occupancy or activity.

Radio telemetry may generate more information on seasonal variability of movements, resource use and home range size because of the ability track individuals over space and time. However, camera trapping allows for sampling of potentially all the individuals in a population and is not as limited by equipment and personnel training costs. Although there appeared to be overlapping home ranges of males and females from our study and in the study by Bülow (1987), we never observed a male and female together at one time, although they did visit the same areas. The observation of young on multiple occasions on both Tiwai and Lower Tiwai provides evidence that pygmy hippos are reproducing successfully in the area. While the sample size was

very small (n = 5), pygmy hippo calf and mother pairs were observed in all seasons. With a low reproductive potential and low population density (Steck 2008), any young are critical to pygmy hippo populations in the region.

Salt licks have been used to study the activity patterns of ungulates in countries like Peru (Tobler et al. 2009). Many ungulate species supplement their mineral requirements by ingesting soil (Ayotte et al. 2006). Local people near Tiwai Island have reported observing pygmy hippos eating residual charcoal from burnt agricultural fields (A. Conway, Chapter 2). In addition to increasing detection probabilities for occupancy modeling purposes, salt licks may also lead to insight on habitat requirements and a further refinement of activity patterns.

MANAGEMENT IMPLICATIONS

Our findings are the first published study on the use of camera traps to estimate activity patterns and occupancy of pygmy hippos. Understanding pygmy hippo biology and ecology is an essential step to permit prioritization of conservation plans. Our surveys indicated pygmy hippos are utilizing the smaller surrounding islands and on Lower Tiwai, which are currently unprotected. By protecting habitat for pygmy hippos, the variety of mammal and avian species recorded on Tiwai Island and Lower Tiwai will also be protected. Both White (1986) and Eichenlaub (1989) advocated for managing the Moa River islands as one large unit, with corridors connecting the Tiwai islands with Kambui Hills Reserves and Gola Rainforest National Park. Interviews with local people suggested pygmy hippos are present on many of these islands both south and north of Tiwai Island, from 20 km north of Tiwai Island to 50 km southward towards the mouth of the Moa (A. Conway, Chapter 2).

During the dry season, river levels drop and expose rocks, which animals may use to cross, and local residents near Tiwai Island report larger species like African forest buffalo

Syncerus caffer nanus) and pygmy hippos move between Kambui Hills and the islands. For example, the young male bongo observed on our camera may have travelled from the Gola Forests. While pygmy hippos in other areas appear to primarily inhabit mature forest and swamps (Mallon et al. 2011), the hippos near Tiwai Island may soon need to adapt to human-modified areas. Buffering the rivers as a management tool may be a solution. With only 5% of Sierra Leone's original forest remaining, pygmy hippos are endangered and their future is far from secure. Wide scale, collaborative conservation initiatives are more relevant now than ever, with deforestation, agricultural expansion and human populations increasing (Norris et al. 2010). Camera trap surveys have the potential for monitoring a little known terrestrial species to inform conservation initiatives. However, protection of key riverine and swampland habitats is critical to pygmy hippo survival and may only be achieved through multi-stakeholder cooperation.

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Table 6.1. Habitat and detection variables included in occupancy modeling analysis (Program MARK) for wildlife species on and around Tiwai Island Wildlife Sanctuary, Sierra Leone.

Abbreviations	Name	Description	
Habitat Variables			
Veg	Forest Type	Categorical (Secondary forest, swamp, riparian)	
Den	Understory density	Categorical (Open, semi-dense, dense)	
Trl	Trail type	Categorical (Animal trail, human transect, no trail)	
Loc	Location	Categorical (Tiwai Island, smaller islands)	
DistMoa	Distance to Moa	Numerical (Range 0 – 1062.3 m) Standardized	
Sea	Season ¹	Rain (May-October) or Dry (November – April)	
Detection			
Trl	Trail type	Categorical (Animal trail, human transect, no trail)	
Den	Understory density Categorical (Open, semi-dense, dense)		
Т	Time	Sampling period (1, 2, 3)	

¹Field Season 2 only
Table 6.2. Mammal and avian species detected on camera traps on and around Tiwai Island

<u>C</u>	C	ΠΙΩΝΪ	Total	
Common name	Scientific name	IUCN	Detections	
Artiodactyla				
Black duiker ¹	Cephalophus niger	LC	2	
Bongo	Tragelaphus eurycerus	NT	1	
Bushbuck ¹	Tragelaphus scriptus	LC	9	
Maxwell's duiker ¹	Philantomba maxwellii	LC	201	
Pygmy hippopotamus ¹	Choeropsis liberiensis	EN	41	
Red river hog ¹	Potamochoerus porcus	LC	93	
Water chevrotain ¹	Hyemoschus aquaticus	LC	42	
Yellow-backed duiker ¹	Cephalophus silvicultor	LC	58	
Carnivora				
African civet ¹	Civettictis civetta	LC	7	
Common cusimanse ¹	Crossarchus obscurus	LC	14	
Common genet ¹	Genetta genetta	LC	4	
Marsh mongoose ¹	Atilax paludinosus	LC	21	
Spotted-necked otter	Lutra maculicollis	LC	2	
Primates				
Black and white colobus	Colobus polykomos	VU	2	
Campbell's monkey ¹	Cercopithecus campbelli	LC	20	
Chimpanzee ¹	Pan troglodytes	EN	20	
Diana monkey	Cercopithecus diana	VU	10	
Green monkey	Chlorocebus sabaeus	LC	4	
Lesser spot-nosed monkey	Cercopithecus petaurista	LC	2	
Olive colobus ¹	Procolobus verus	NT	1	
Sooty mangabey ¹	Cercocebus atys	VU	328	
Rodentia				
Brush-tailed porcupine ¹	Atherurus africanus	LC	19	

Wildlife Sanctuary, Sierra Leone, from 2008-2011

Squirrel ¹	Sciuridae	LC	9
Birds			
African goshawk	Accipiter tachiro	LC	1
African olive ibis	Bostrychia olivacea	LC	5
African pied hornbill	Tockus fasciatus	LC	1
Blue-breasted kingfisher	Halcyon malimbica	LC	3
Crested guineafowl	Guttera pucherani	LC	3
Grey kestrel	Falco ardosiaceus	LC	1
Pied Crow ¹	Corvus albus	LC	1
Tambourine dove ¹	Turtur tympanistria	LC	9
White-breasted guineafowl ¹	Agelastes meleagrides	VU	6
White-crested hornbill ¹	Tropicranus albocristatus	LC	9
Unknown bird or mammal ¹			50
Nile monitor ¹	Varanus niloticus	DD	3

[†]The IUCN Red List of Threatened Species, 2013

¹Detected on Lower Tiwai Island

	Se	easons Co	mbined			Field S	eason 2	
Model	K	AIC ^a	ΔAIC_{c}^{b}	W	K	AIC ^a	ΔAIC_{c}^{b}	W
$\psi(\text{Veg})p(.)$	4	195.96	0.00	0.36	4	129.68	3.42	0.05
$\psi(\text{Loc})p(.)$	3	197.27	1.31	0.18	3	127.19	0.93	0.17
$\psi(\text{Veg})p(t)$	6	197.69	1.73	0.15	6	131.97	5.71	0.02
$\psi(Loc)p(t)$	5	198.86	2.90	0.08	5	129.38	3.11	0.06
ψ(.)p(.)	2	199.46	3.50	0.06	2	126.26	0.00	0.27
ψ(Den)p(.)	4	200.92	5.00	0.03	4	128.49	2.23	0.09
ψ(.)p(t)	4	200.96	5.00	0.03	4	128.37	2.11	0.09
ψ(DistMoa)p(.)	3	201.10	5.14	0.03	3	128.39	2.13	0.09
ψ(.)p(Den)	4	201.16	5.20	0.03	4	128.34	2.08	0.10
$\psi(\text{Season})p(.)^{c}$	3	201.50	5.54	0.02				
ψ(.)p(Trl)	4	202.01	6.05	0.02	4	130.39	4.13	0.03
ψ(Trl)p(.)	4	202.49	6.53	0.01	4	130.34	4.08	0.04

Table 6.3. Summary of all model selection results with number of parameters (K), AIC_c , ΔAIC_c , and model weight (*w*) to determine covariates influencing occupancy (ψ) and detection

(p) for the pygmy hippopotamus Choeropsis liberiensis in Sierra Leone from 2008-2011

^aAkaike's Information Criterion was adjusted for small sample size

^bAIC*c* difference between model with lowest AIC*c* and each other model.

^cData deficient for Season 2 alone

Season Parameter	B	$\frac{SE}{SE} = \frac{95\% CI}{95\% CI}$			
Season 2	P	SE			
ψ(.)p(.)					
$\psi(\operatorname{Loc})p(.)$					
Tiwai Island	-0.89	0.64	-2.16	0.38	
Smaller Islands	1.57	1.85	-2.10	5.20	
Combined					
$\psi(\text{Veg})p(.)$					
Secondary Forest	-1.02	0.58	-2.15	0.11	
Swamp	0.48	1.09	-1.66	2.62	
Riparian	2.53	2.04	-1.48	6.54	
$\psi(\operatorname{Loc})p(.)$					
Tiwai Island	-0.77	0.58	-1.91	0.36	
Small Island	2.68	3.42	-4.02	9.37	
$\psi(\text{Veg})p(t)$					
<i>p</i> 1	-2.11	0.76	-3.61	-0.62	
<i>p</i> 2	1.04	0.69	-0.32	2.40	
<i>p</i> 3	0.78	0.70	-0.60	2.16	
Secondary Forest	-1.02	0.59	-2.17	0.13	
Swamp	0.41	1.07	-1.69	2.51	
Riparian	2.50	2.02	1.45	6.45	

Table 6.4. Parameter estimates for occupancy models results to determine occupancy as a factor of covariates for the pygmy hippopotamus *Choeropsis liberiensis* on and around Tiwai Island from 2008-2011. Models with $\Delta AICc < 2$ are shown.

1100		<u>ν</u>	SE	95%	$\frac{CI}{CI}$	p	SE	95% CI	
Season 2						-			
	ψ(.)p(.)	0.32	0.14	0.11	0.63	0.21	0.10	0.07	0.46
	ψ(Loc) <i>p</i> (.)								
	Tiwai Island	0.29	0.13	0.10	0.59	0.21	0.10	0.10	0.46
	Smaller Islands	0.66	0.46	0.04	0.99	0.21	0.10	0.10	0.46
Combined									
	$\psi(\text{Veg})p(.)$								
	Secondary Forest	0.26	0.11	0.10	0.53	0.21	0.09	0.09	0.42
	Swamp	0.37	0.27	0.06	0.85	0.21	0.09	0.09	0.42
	Riparian	0.82	0.35	0.04	0.99	0.21	0.09	0.09	0.42
	$\psi(\text{Loc})p(.)$								
	Tiwai Island	0.37	0.18	0.12	0.72	0.21	0.09	0.09	0.42
	Smaller Islands	0.87	0.42	0.01	0.99	0.21	0.09	0.09	0.42
	$\psi(\text{Veg})p(t)$					0.25	0.11	0.10	0.52
	<i>p</i> 1					0.21	0.10	0.10	0.45
	<i>p</i> 2					0.11	0.07	0.03	0.35
	<i>p</i> 3								
	Secondary Forest	0.36	0.18	0.11	0.73				
	Swamp	0.35	0.26	0.05	0.84				
	Riparian	0.81	0.35	0.04	0.99				

Table 6.5. Summary of model selection results to determine occupancy as a factor of covariates and detection rates for the pygmy hippopotamus *Choeropsis liberiensis* on and around Tiwai Island from 2008-2011 Models with $\triangle AICc \le 2$ are shown



Figure 6.1. Study area Tiwai Island and Lower Tiwai Island and surrounding Gola Forest and Kambui Hills for camera surveys of pygmy hippopotamus *Choeropsis liberiensis* and other species in Sierra Leone from 2008-2011.



Figure 6.2. Plot of occupancy rates as a function of distance from the Moa River for pygmy hippopotamus *Choeropsis liberiensis* on and around Tiwai Island, Sierra Leone



Figure 6.3. Location of all pygmy hippopotamus *Choeropsis liberiensis* events at camera
locations between rainy and dry seasons on Tiwai Island, Sierra Leone from 2008-2011.
Varying size of points indicates frequency pygmy hippopotamus visited that camera.



Figure 6.4. Location of all pygmy hippopotamus *Choeropsis liberiensis* events at camera locations on Lower Tiwai Island, Sierra Leone during 2011.



Figure 6.5. Monthly activity patterns for *Choeropsis liberiensis* based on camera trap data on and around Tiwai Island Wildlife Sanctuary, Sierra Leone. Dotted line signifies the overall average camera trap event per 100 trap nights.



Figure 6.6. Activity levels by proportion of photographs for the pygmy hippopotamus (*Choeropsis liberiensis*) based on pooled camera trapping records (n = 95) on and around Tiwai Island Wildlife Sanctuary, Sierra Leone from October 2008 to July 2011. Dotted line signifies beginning and end of nocturnal period.



Figure 6.7. Hourly activity levels by proportion of photographs for the pygmy hippopotamus *Choeropsis liberiensis* between dry (November–April) and wet season (May-October) based on pooled camera trapping records (n = 95) on and around Tiwai Island Wildlife Sanctuary, Sierra Leone from October 2008 to July 2011.



Figure 6.8. Hourly activity levels by proportion of photographs for the pygmy hippopotamus *Choeropsis liberiensis* between new moon and full moon based on pooled camera trapping records (n = 95) on and around Tiwai Island Wildlife Sanctuary, Sierra Leone from October 2008 to July 2011.

CHAPTER 7

PYGMY HIPPOPOTAMUS CONSERVATION IN SIERRA LEONE: SUMMARY OF FINDINGS AND FUTURE CONSIDERATIONS

SUMMARY

In this final chapter, we summarize the main results, which explore pygmy hippopotamus *Choeropsis liberiensis* interactions with humans, technique development for *in situ* research, and some novel findings for pygmy hippopotamus (hereafter pygmy hippo) occupancy estimation and activity patterns. We follow with a brief discussion of the broader significance and conservation implications.

In Chapter 1, we examined the literature on pygmy hippo natural history, survey techniques for rare species, and introduced concepts in the estimation of occupancy. We also set the historical and geographical context for the study area, Tiwai Island Wildlife Sanctuary and the surrounding areas, to establish a foundation for the research. In Chapter 2, we explored local knowledge in villages along the Moa River in Sierra Leone using semi-structured surveys and questionnaires, specifically assessing local residents' awareness of and attitudes toward the pygmy hippo. Although only 22% of questionnaire respondents acknowledged benefits related to hippo conservation, the proportion increased significantly if residents were exposed to conservation outreach, were older or owned livestock. Chapter 3 focused on using local knowledge to characterize human-wildlife interactions around a protected area and evaluated the feasibility of a participatory citizen science approach to wildlife research by exploring the potential benefits and challenges. We found that many wildlife species in these areas are viewed

as crop pests and bushmeat appeared to be a preferred source of protein. Pygmy hippos were ranked in neither the top crop pests nor were they a preferred meat source. However, approximately a fourth of survey respondents believed pygmy hippos damage crops. Collaborating with local people on environmental outreach and in scientific research helps to bridge the gap between a need for more ecological knowledge on a little known species and the promotion of biodiversity conservation in local communities. However, public participation in this region faces complex logistical, economic and cultural challenges. We explored possible solutions to these hurdles remaining as public participation-style projects expand to encompass new audiences in developing countries.

In Chapter 4, we tested four radio telemetry attachment designs, including a hock mount, harness, neck collar and modified neck collar on two captive female pygmy hippos in the Gladys Porter Zoo. The hock and harness attachments detached from the pygmy hippo and the first traditional flat neck collars resulted in significant abrasion. The modified neck collar caused minimal abrasions and remained around the neck for an extended period of time. Therefore, we determined a tube-shaped collar the best option for use in radiotelemetry. In Chapter 5, we evaluated and implemented pitfall traps for radio collar attachment on and around Tiwai Island. A trial period from August to October 2010 resulted in the safe capture and release of a male pygmy hippo. However, when we attempted to capture more individuals for radio collar placement, we had many visitations near the traps and several misses, where a pygmy hippo fell into the trap and escaped. We used salt licks and trap modifications to increase visits to the traps, but were unsuccessful at capturing another hippo. We recommended a longer capture period, with a minimum of three consecutive months and more than 20 traps. Furthermore, we discussed our preliminary success with salt as an attractant, and advised future researcher about the perils

of capture periods in rainy season. During this time, traps were prone to flooding and the tops of the traps collapsed after saturating with water.

Chapter 6 investigated the use of camera traps as a technique for assessing occupancy and detection of pygmy hippos. In addition to pygmy hippos, 23 mammal species and 11 avian species were recorded on our camera traps, with sooty mangabeys the most often detected species. Pygmy hippos had a very low detection probability, but had a higher probability of occupancy in riparian and swamp habitats and on the smaller surrounding islands. Occupancy rates decreased with distance from the river. Pygmy hippos were mainly nocturnal and had activity peaks from 20:00-22:00 and 01:00-03:00 hours, and were active in the late morning only in rainy season.

CONCLUSION

Our research sought to contribute to several objectives outlined in the Conservation Strategy for the Pygmy Hippopotamus (Mallon et al. 2011), in which poaching pressure is reduced, pygmy hippos are recognized as a flagship species, and status in the range state is assessed. We surveyed rural residents, conducted environmental education, and evaluated techniques to monitor hippo populations. A range-wide survey has been advocated by Collen et al. (2011) and Mallon et al. (2011). However, intensively focused studies, such as camera trapping and radio telemetry, provide valuable insight into pygmy hippo ecology and behavior. Technology and application of camera traps is advancing at a rapid pace, and cameras are ideal for cryptic species with low detectability like the pygmy hippo. Radio telemetry is urgently needed to obtain data on movements, habitat selection, and home range size. Further research should focus not only on Tiwai Island Wildlife Sanctuary, but extend to the Moa River islands and the corridors between Gola Rainforest National Park and Kambui Hills Reserves.

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The Upper Guinea rainforests play a key role in global biodiversity; however, with human populations intrinsically linked to natural resources, managing these systems with a topdown approach excluding local stakeholders may result in collapse of conservation initiatives (Adams et al. 2004). Aside from providing preliminary guidance for conservation planning, our results also demonstrate the need for incorporating local people into decision-making. Sierra Leone is one of the most impoverished countries in the world, ranked 180 out of 187 (UNDP 2011). Conservation is complex in an area where people are struggling for daily survival. With increasing human populations and a subsequent need for increased agricultural land, mature forests and the pygmy hippo habitats they encompass are further degraded or lost. Without protection, pygmy hippo populations across all range countries will continue to be threatened with extirpation or extinction. Effective management and enforcement is needed to protect areas from illegal logging, poaching and agricultural encroachment, and should be a high priority for conservation practitioners and government agencies alike. Mitigating human-wildlife conflicts should also be a high priority in human-modified landscapes like the areas surrounding the Tiwai Island Wildlife Sanctuary. Understanding the human impacts to pygmy hippo and other threatened wildlife is crucial to conservation of biodiversity. Effective outreach programs in these areas may encourage dialogue between local people and scientists, improve scientific research outcomes, and lead to a stronger foundation for development of endangered species conservation plans (Brewer 2002). Novel insights provided throughout this dissertation highlight the value of development of survey techniques for cryptic species and the inclusion of humans into conservation initiatives.

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APPENDIX A

QUESTIONNAIRE SURVEYS FOR CHAPTER 2 AND CHAPTER 3

Version 1

Interviewer: _____ Date: _____ Time: ____ Village Code: _____

We want to learn more about your life, the place where you live, and your opinions regarding the forests and wildlife around your village. Please take a few minutes to answer the following questions. Thanks for your help!

<u>Pygmy Hippo Encounters.</u> Please answer the following questions about your experiences with pygmy hippos.

1. <u>How many pygmy hippos have you seen since last rainy season?</u>

1a. If >1, have you seen the same pygmy hippo more than once?

2. <u>Where did you see the pygmy hippos?</u> In River Barri Mainland Koya Mainland Tiwai Island

Other island On the farm Other_____

3. What do pygmy hippos like to eat?

<u>Conservation</u>. Please answer the following about wildlife, people, and conservation around your village.

4. <u>Has wildlife ever caused damage to your crops?</u> YES NO UNSURE

 4a. If yes, which crops?
 Cassava ()
 Rice()
 Groundnuts()
 Beans()

 Sweet potatoes()
 Yams()
 Okra()
 Maize ()
 Millet()
 Bananas ()

 Plantains()
 Coconuts()
 Cacao()
 Coffee ()
 Kola()
 Coco yams()

 Oil Palm()
 Krin krin()
 Pumpkin()
 Papaya ()
 Pepper ()
 Cucumber ()

5. <u>Which 3 animals cause the most damage to villagers' crops?</u> Red river hog() Squirrels()

Porcupines () Birds() Pygmy Hippo() Cutting grass() Monkeys() Duikers() Chimpanzee() Water chev () Rat() Bushbuck() Water buffalo()

6. <u>Do pygmy hippos cause damage to crops?</u> YES NO UNSURE6a. If yes, which crops?

7. How do you protect crops? Traps Spend night Noise making Fence Scarecrows Trenches Poisoning Rituals Other 8. <u>Which type of wild meat do people catch most often?</u> Red River Hog Monkey Cutting grass Porcupine Chimpanzee Bat Bird Pygmy hippo Water chevrotain Bushbuck Rat Mongoose Squirrel Yellow-backed duiker Maxwell's duiker 9. Which type of wild meat is the sweetest to eat? Red River Hog Monkey Cutting grass Porcupine Chimpanzee Bat Bird Pygmy hippo Water chevrotain Bushbuck Rat Mongoose Squirrel Yellow-backed duiker Maxwell's duiker Other 10. Are there any animals that you cannot eat? YES NO UNSURE 10a. If yes, which ones?? 11. Do pygmy hippos benefit the local villages? YES NO UNSURE

11a. Yes, Why? Bring visitors Bring researchers Harmless MeatSpiritual11b. No, Why not?Damage cropsDangerousNo useUnsureOther

Opinions About Forests and Wildlife. Please tell us if you disagree, have no opinion, or agree with the following statements about wildlife and forests.

12. It is necessary to protect Tiwai Island from people	DIS	N/O	AGREE
13. Wildlife provides food for people	DIS	N/O	AGREE
14. Farming should be allowed on Tiwai Island	DIS	N/O	AGREE
15. People who poach should be punished by the police	DIS	N/O	AGREE
16. It is necessary to protect <i>some</i> forests from people (not all)	DIS	N/O	AGREE
17. Villagers should be allowed to hunt for food to eat	DIS	N/O	AGREE
18. Logging of <i>some</i> trees should be allowed on Tiwai Island	DIS	N/O	AGREE
20. Wild animals that cause big crop damage should be killed	DIS	N/O	AGREE
21. Selling wild meat is a good way to get money	DIS	N/O	AGREE
22. Research on Tiwai Island helps the villages	DIS	N/O	AGREE
23. Diamond mining should be allowed on Tiwai Island	DIS	N/O	AGREE
24. People who poach should be punished by local chiefs	DIS	N/O	AGREE
25. Pygmy hippos cause damage to crops	DIS	N/O	AGREE
26. Tourism on Tiwai Island helps the villages	DIS	N/O	AGREE
27. Diamond mining causes damage to forests	DIS	N/O	AGREE
28. Villagers should be allowed to hunt for food as much as they want	DIS	N/O	AGREE
29. It is necessary to protect <i>all</i> forests from people	DIS	N/O	AGREE
30. Tiwai Island benefits people in local villages	DIS	N/O	AGREE

31. Hunting wildlife should be allowed on Tiwai Island
32. Wild meat is sweeter than domestic meat (goat, chicken, etc)
33. People should be allowed to set traps for animals on their farms
Version 2

Interviewer: _____ Date: _____ Time: ____ Village: _____

<u>Pygmy Hippo Encounters.</u> Please answer the following questions about your experiences with pygmy hippos.

1. <u>How many pygmy hippos have you seen since last rainy season?</u>

1a. <u>How many different hippos?</u>

2. Where did you see the pygmy hippos? In river Barri Mainland Koya Mainland Tiwai

Island Other Island On the farm Other

3. What do pygmy hippos like to eat?

<u>Conservation</u>. Please answer the following about wildlife and conservation efforts around your village.

4. <u>Has wildlife ever damaged your crops?</u> YES NO UNSURE

 4a. Which crops and what animals? Cassava() Rice() Groundnuts() Bean()

 Sweet potatoes() Yams() Okra() Corn() Millet() Bananas()

 Plantains() Coconuts() Cacao() Coffee() Kola() Cocoyams()

 Oil Palm() Krinkrin() Pumpkin() Papaya() Pepper() Cucumber()

5. <u>Which 3 animals cause the most damage to crops</u>? Red river hog() Squirrel()

Porcupine ()Bird()Pygmy hippo()Cutting grass()Monkey()Duiker()Chimpanzee()Water chevrotain()Rat()Bushbuck()Buffalo()

- 6. Do pygmy hippos cause damage to crops? YES NO UNSURE6a. If yes, which crops?
- 7. <u>How do you protect your crops?</u> Snares Pit traps Make noise Fence Scarecrow Trench Poison
- 8. Which wild meat do people catch most often in traps? Red river hog Monkey Cutting grass Porcupine Chimpanzee Bat Bird Pygmy hippo Water chevrotain Bushbuck Rat Mongoose Squirrel Yellow-backed duiker Maxwell's duiker Buffalo Rabbit Snake Other ______

- 9. Which wild meat is the sweetest to eat? Red river hog Monkey Cutting grass Porcupine Chimpanzee Bat Bird Pygmy hippo Water chevrotain Bushbuck Rat Mongoose Squirrel Yellow-backed duiker Maxwell's duiker Buffalo Rabbit Snake Other
- 10. <u>Are there any animals that you cannot eat?</u> YES NO UNSURE 10a. If yes, which ones?
- 11. Is there a benefit of pygmy hippos to local villages and people? YES NO UNSURE
 11a. If Yes, WHY? Bring visitors Bring researchers Harmless Meat Beautiful
 11b. If No, WHY? Damage crops Dangerous No use Unsure Other
 12. Have you ever heard of Tiwai Island? YES NO UNSURE

12a. If so, do you believe TIWS should be protected from people? YES NO UNSURE

OPINIONS ABOUT FORESTS AND WILDLIFE

13. It is necessary to protect river islands from people	DIS	N/O	AGREE
14. Wildlife provides food for people	DIS	N/O	AGREE
15. Farming on the islands is better than farming on the mainland	DIS	N/O	AGREE
16. People who hunt illegally in forests should be punished by police	DIS	N/O	AGREE
17. Pygmy hippo meat is very sweet	DIS	N/O	AGREE
18. More islands should be protected like Tiwai Island	DIS	N/O	AGREE
19. Wild animals that cause big crop damage should be killed	DIS	N/O	AGREE
20. Logging should be allowed on all islands	DIS	N/O	AGREE
21. Selling wild meat is a good way to get money	DIS	N/O	AGREE
22. Research of wildlife can help local villages	DIS	N/O	AGREE
23. Diamond mining should be allowed on all islands	DIS	N/O	AGREE
24. People who hunt illegally in forests should be punished by chiefs	DIS	N/O	AGREE
25. Pygmy hippos cause damage to crops	DIS	N/O	AGREE
26. Tourism in Sierra Leone helps local villages	DIS	N/O	AGREE
27. Diamond mining causes damage to forests	DIS	N/O	AGREE
28. People should be allowed to hunt for as much meat as they want	DIS	N/O	AGREE
29. It is necessary to protect some forests from people	DIS	N/O	AGREE
30. Wild meat is sweeter than domestic meat	DIS	N/O	AGREE
31. The islands have more wildlife than the mainland	DIS	N/O	AGREE

32. There are more wild animals now than there were before the war DIS N/O AGREE
33. Pygmy hippos are a nuisance DIS N/O AGREE
Demographic information for both versions
Gender: M F
Marital Status: Single Married Divorced Widowed Relationship
Occupation Hunter Farmer Fisherman Merchant Teacher Student Carpenter Other
Age: ______ # in household ______ Livestock: YES NO What kind?
Education: None Primary Junior Secondary Senior Secondary University Arabic
Resident Status: Immigrant Native
If immigrant, how long? 0-5 5-10 10-15 15-20 20+

APPENDIX B SEMI-STRUCTURED SURVEYS FOR CHAPTERS 2 AND 3

- 1. Have you ever seen a pygmy hippopotamus?
 - a. When did you see the animal? How long ago did you see it?
 - b. Where did you see the hippo?
 - c. What time of day did you see the animal?
 - d. What was the hippo doing?
- 2. What do pygmy hippos eat?
- 3. Do pygmy hippos eat people's gardens?
- 4. Are there benefits to pygmy hippos?
- 5. How do people hunt pygmy hippos?
- 6. Have pygmy hippos been hunted recently?
- 7. Have you seen any changes in wildlife since you were a child?
- 8. What are the differences in wildlife on Tiwai and the dryland?
- 9. Do you have any pygmy hippo stories?
- 10. Are there any benefits to Tiwai?
- 11. If you were the bossman for Tiwai, what would you do?
- 12. Would you allow hunting, mining, fishing, farming on Tiwai?
- 13. Any other stories?

Gender:

Age:

Occupation:

Village:

Native/Immigrant:

Optional Questions

- 1. Have people in this village ever eaten pygmy hippo meat? (Further explain confidentiality)
 - a. Did they find the animal already dead?
 - b. Did they kill the animal?
 - c. If they killed it, was it for the meat, or for protection (of property and persons)?
- 2. Do people get angry about crops? What can you do to keep a pygmy hippo out?
- 1. What are some of the problems you see with working with researchers? How can these problems be resolved?
- 2. What new things have you learned about Tiwai/wildlife that you never knew before this project started?
- 3. In what ways do you think the villagers have contributed to my research?
- 4. How do you think people could continue my work after I leave?
- 5. What are some of the challenges to continuing the work?
- 6. What makes people willing to help with research and science on Tiwai?
- 7. Do you think research is important for Tiwai? Why?
- 8. How can researchers make villagers more involved in pygmy hippopotamus conservation?
- 9. Do you think it would be possible for villagers to collect data to help with the hippopotamus research? What do you think they could do?

APPENDIX C PHOTOGRAPHS OF PREVIOUSLY UNDOCUMENTED SPECIES







