Habitat suitability modelling to guide long-term conservation strategies for the pygmy hog in Assam

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DECLARATION OF OWN WORK

I declare that this thesis, “Habitat suitability modelling to guide long term conservation strategies for the pygmy hog in Assam,” is entirely my own work, and that where material could be construed as the work of others, it is fully cited and referenced, and/or with appropriate acknowledgement given.

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Abstract:

Understanding the habitat requirements and the distribution of a species is critical for its conservation, as it can inform us of its needs for survival and where to target conservation action. The pygmy hog (*Porcula salvania*) is a critically endangered suid, existing in just three populations in India, having been extirpated across its estimated former range in the Terai grasslands. It is therefore of utmost importance determine its former distribution, to understand its habitat use and to develop methods to understand which areas across its range are suitable for consequent reintroductions.

The study contributed to this effort looking at the programme in the past, present and the future, investigating the historical distribution of the species, building a habitat suitability model to identify suitable areas for reintroduction and also evaluating the failure of the 2015 release programme. The study showed that the species did exist across its estimated range, discovering two new presence records of the species. The study also evaluated the failure of the 2015 release of the species. The habitat suitability model showed considerable suitable areas in India and Nepal, identifying protected areas as potential survey sites for future reintroductions.
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Abbreviations

GARP: Genetic Algorithm
HS: Habitat Suitability
ONP: Orang National Park
PH: Pygmy Hog
PHCP: Pygmy Hog Conservation Programme
SDM: Species Distribution Modelling

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CHAPTER 1: INTRODUCTION

1.1 Problem statement

To combat species population declines at local and global scales, conservation efforts around the world have increasingly sought to promote the survival of endangered and threatened species by re-establishing new populations through reintroductions. Reintroduction of rare and endangered species which are characterised by restricted geographic ranges, habitat sizes and small population sizes is an important technique for the unprecedented extinction rate the world is experiencing. (Aitken et al., 2007; Lavergne et al., 2005; Medrano and Herrera, 2008; Rabinowitz, 1981; Scott and Carpeted, 1987; D.E. Brown, 1988).

Species reintroduction is one of the successful conservation techniques for restoration of the depleted species populations, and degraded habitats and ecosystems (Leaper et al., 1999; Martinez-Meyer et al., 2006; Ren et al., 2009; Zai et al., 2009; Rodríguez-Salinas et al., 2010; Nazeri et al., 2010). The term “reintroduction” is used to describe the release of a species into the wild in order to restore the species to an area where it used to formally occur but where it is now absent (IUCN, 1998). A movement which started with large vertebrates and most often, charismatic species, reintroductions have now occurred for at least at least a hundred years (Kleiman, 1989). Reintroduction of locally extirpated species has become a common tool for the conservation and management of wildlife species, the end goal being to establish a self sustaining population within its historical range, with a high chance of sustainability with minimal intervention in the long term (Van Wieran, 2006; Griffith et al., 1989; Seddon et al. 1999). There have been some high profile success stories like the case of the black footed ferret (Mustela nigripes), the Arabian oryx (Stanley Price 1989), and the California condor (Gymnogyps californianus) (Toone and Wallace, 1994) that increased the awareness of reintroduction as a viable option for conservation of species.

However, the success rate has been less than 50% so far (Griffith et al., 1989; Kleiman, 1989; Fischer & Lindenmayer, 2000). While it is generally accepted that a successful reintroduction or translocation program requires ‘good quality’ habitat (Kleiman, 1989), a frequently cited reason for program failure is insufficient knowledge of what determines habitat quality (Griffith et al., 1989; Wolf et al., 1998). Therefore generating knowledge and distribution data is of particular importance for these species. In order to successfully reintroduce and rehabilitate the threatened species in the ecosystem, a detailed knowledge on the distribution of their potential habitats is essential. Another importance for the low success rate is that of the lack of post release monitoring, which despite their importance are
often poorly designed and hence provide less informative results (Legg and Nagy, 2006, Field et al. 2007). Habitat distribution models which establish relationships between occurrences of species and environmental conditions in the study area therefore help to identify the areas for species reserves, reintroduction and in developing effective management measures (Osborne et al. 2009) Investigation of potential suitable habitat for rare and endangered species is critical for monitoring and re-establishment of the declining native populations in their natural habitat (Gaston, 1996).

1.2 Importance of the pygmy hog and the study:

The pygmy hog (Porcula salvania) is the smallest and the rarest wild suid in the world (Anon 1985; Oliver and Deb Joy 1993). Having been exterminated from most of its original range they just exist in three disjunct populations in India. Categorised as critically endangered and listed as Schedule 1 in the Indian Wildlife (Protection) Act, the species is on the brink of extinction. Officially initiated in 1995, the Pygmy Hog Reintroduction Programme (PHCP) was formed under the aegis of an ‘International Cooperative Management and Research Agreement (ICMRA), between the Ministry of Environment and Forest (Government of India), the Assam State Forest Department, the Durrell Wildlife Conservation Trust and the IUCN Wild Pig Specialist group. The PHCP was started with the primary objective to aid the implementation of a broad conservation action for the species, to

The terai habitat, the dry savannah grasslands of the Himalayan foothills, which besides being a highly threatened habitat in itself is also home to and is crucial to the survival of a number globally endangered species such as the greater one horned rhinoceros (Rhinoceros unicornis), the Royal Bengal tiger (Panthera tigris), Eastern barasingha (Ruservus duvaucelli), water buffalo (Bubalus bubalis), the hispid hare (Caprolagus hispidus) and the Bengal florican (Houbaropsis bengalensis). Pygmy hogs are one of the most useful indictors of current wildlife management practices especially the effects of widespread, too frequent burning and the other pressures that exploit the habitat (Oliver 1980, 1981, 1984 and 1991).

Considering the species critical status in the wild, there is an immediate need to increase the number of individuals in the wild. In order to establish a viable population in the wild, across the species range, there needs to be a comprehensive study of the species habitat use and consequently the habitat selection. There is also a need to look further, take a long term approach to the species conservation, identifying suitable areas for the species consequent reintroduction in areas where they no longer exist. Before doing so, there is a should be a comprehensive study that looks into the historical distribution of the species, since one of the
prerequisites of reintroducing a population is that it should be reintroduced in areas where they previously existed (IUCN, 1998).

1.3. Aims and objectives:

The aim of the study is to contribute to the Pygmy Hog Conservation Programme (PHCP) on the whole, improving understanding of the natural distribution of natural distribution and the habitat needs of the species, thereby helping to focus the reintroduction programme in appropriate areas and habitat types. I discuss the small scale habitat use of the reintroduced individuals post release. I then collate the sparse information available on the former distribution of the pygmy hog to confirm the historical presence of the species. Based on this, I update the current IUCN map of the pygmy hog’s historical and current range. Using data on the habitat correlates of presence of pygmy hogs in its current range, I develop a habitat suitability model. This enables me to identify suitable sites for future reintroductions of the pygmy hogs across its former range, based on the overlap of suitable locations and protected areas.

It is important that the organisations involved in the conservation of the pygmy hogs be able to identify suitable areas, extensions of protected area networks and sites for the future reintroduction of the individuals to boost numbers (Schulze and Groves, 2004), in which species distribution models can play a very important role.

The objectives of the study are:

1. To assess the short-term success of the release of pygmy hogs as part of the reintroduction programme for the species.
2. To determine the historical locations of the species across the whole of its former range and update the existing map.
3. To make a habitat suitability model based on current presence points and extrapolate it across the species across the species former range to identify suitable areas for pygmy hog survival.
4. To identify protected areas as potential survey sites for future reintroductions of pygmy hogs.
CHAPTER 2. BACKGROUND

2.1. Role of reintroductions in nature conservation:

According to IUCN (1998), a reintroduction is “an attempt to establish a species in an area which was once part of its historical range, but from which it has been extirpated or extinct” while the term reintroduction biology refers to the research undertaken to improve the effects of reintroductions (Armstrong 2007). Reintroductions have occurred for the last 100 years globally but the field of reintroduction biology was born much later in response to the low success rates reintroductions worldwide (Armstrong 2007). Reintroduction is a very widely used conservation tool, having been recommended in 64% of 314 recovery plans for endangered species within the United States alone (Tear et al. 1993). Although increasingly common it has been a controversial tool in the conservation of endangered species, in terms of the risk factor, the high chance of failure and also the high costs involved. (Fischer and Lindenmayer 2000; Griffith et al. 1989; Sarrazin and Barbault 1996; Seddon et al. 2007; Wolf et al. 1996; Lindburg, 1992). Reintroduction potential was realised as a viable conservation tool following several high profile reintroductions of charismatic species such as the Arabian Oryx (Oryx leucoryx), black footed ferret (Mustela nigripes), California condor (Gymnogyps californianus), Mauritius kestrel (Falco punctatus), the golden lion tamarin (Leontopithecus rosalia) and the European bison (Bison bonasus) (Campbell 1980; Conway 1980; Snyder & Snyder 1989; Stanley Price 1989; Phillips 1990; Myers & Miller 1992; Jones et al. 1995).

It is important to consider the importance and the potential benefits of reintroductions and the released individuals. They might increase the natural biodiversity; fulfil roles as keystone components of an ecosystem or to increase political support to put the necessary species and the related habitat protection in place (Seddon, 1999).

2.2. Measuring success in reintroductions:

There is a fundamental question common to all reintroductions programmes- “by what criteria should we assess success”? (Seddon et al., 2009). A variety of definitions for success have been discussed, some of them being breeding by a first wild-born generation (Sarrazin et al. 1996), a three year breeding generation with the births exceeding adult death rate (Sarrazin et al., 1996), a wild population of at least 500 individual that are unsupported (Beck et al., 1994) or the establishment of a self sustaining populations (Beck et al., 1994), the latter being one of the most commonly used definitions.

Immediate success is often measured through collection of demographic data to quantify survival and the reproduction rates, ideally the rates being the same as the population of the
same species in the wild (Beck et al. 2007). This particular data may then be used to develop population models for predicting the long term success in terms of the population viability probabilities and for guiding reintroduction decision making (Seddon et al., 2007).

For a practitioner, the most important outcomes of post release monitoring are to assess the success of the reintroduction (Richard-Hansen et al. 2000; Strum 2005). Though many studies state that the goal of any reintroduction programme is to establish a viable, self-sustaining population, Seddon (1999) state that it is not the only criterion of success. Instead, some of the criteria that should support reintroductions should be; survival of the release generation, breeding by the release generation and their offsprings and the persistence of the reintroduced populations. Seddon (1999) state that, “The ultimate objective of any reintroduction programme is population persistence without intervention. But that is a state, not a result, and it is assessable only through long, term post release monitoring”

2.3. Tools used in guiding design of the reintroduction programme and ensuring its success:

2.3.1. Post release monitoring; radio telemetry in reintroduction programmes

Post release monitoring is an important aspect of reintroduction projects (Beck et al. 2007; IUCN 2002; Seddon.,1999) whose results can be used to answer many questions, be it of the focal species in question or to the ecological principles at play. (Armstrong and Seddon 2008; Nicoll et al. 2003; Parker 2008; Sarrazin and Barbault 1996). A review of the changing status of reintroduction attempts over a five year period found that four out of 74 projects (5%) were categorised as successful in 1987, had declining populations by 1993(Wolf, C.M et al, 1996). One of the ways of monitoring species post release is that by that of radio telemetry.

One of the most used methods in monitoring animals post release is that by radio tracking, which has made an invaluable contribution to the field of conservation (Cagnacci et al., 2010). VHF radio-tracking is the standard technique that has been in use since 1963. Following the introduction of radio transmitters, radio telemetry has emerged as a well-known method for researching physiology, animal movements, survival, animal abundance and resource selection (Amelon et al., 2009). These consequent advancements have revolutionized radiotelemetry studies and made it possible to use this tool for increasingly smaller species (Amelon et al., 2009). Radio telemetry has been used to check causes and rates of mortality in studies of wildlife (Swenson et al. 1999). Nevertheless, VHF radio-tracking is by far the most useful and versatile type of radio-tracking, for not only does it yield
location data, but it also allows investigators to gather a variety of other types of information (Mech 1974, 1980, 1983). Radio-tracking brought two new advantages to wildlife research: the ability to identify individual animals and the ability to locate each animal when desired. These advantages have led to the wide application of radio-tracking since the first complete workable system was designed (Cochran and Lord 1963). It has been used to study animals as varied as snakes, crayfish, dolphins, tigers, and elephants and in most major countries.

Some mammals do not retain collars, which are the most used forms of radio tracking equipment, since they do not have prominent necks. For example, mammals such as hedgehogs (Morris 1966), badgers (Kruuk, 1978; Cheeseman and Mallinson, 1980) and dolphins (Jennings and Gandy, 1980) have instead been fitted with backpack harnesses. Tail harnesses have been used to fit animals with short stocky necks such as manatees (Priede and French, 1991). Some alternatives to applying collars or harnesses on mammals include ear-tag transmitters (Servheen et al., 1981), transmitters fixed with adhesive directly onto the mammal such as bats (Stebbings, 1982) or bears (Anderka, 1987).

The use of radiotelemetry requires an understanding of the techniques, limitations, and appropriate applications of this tool. Kenward (1987, 2001), White and Garrott (1990), Millspaugh and Marzluff (2001), and Fuller et al. (2005) provide reviews and detailed information on the technology, study design, and analysis of radiotelemetry for wildlife studies. The key things to be kept in mind include selection of animals, the number of animals, and the number of locations per animal (Worton, 1995; Seaman et al., 1999). Gender, age, reproductive condition, geographic location, and other unique characteristics contribute to variability or bias; therefore, stratification by sex or age is recommended when inference objectives dictate (White and Garrott, 1990).

**2.3.2. Species distribution modelling to aid design of reintroduction programmes**

Species distribution models (SDMs; Guisan and Zimmerman, 2000; Guisan and Thuiller, 2005) have been increasingly used to understand the ecology of rare and endangered species, as well as the environmental pressures affecting them (Silva et al. 2014). They have been used to inform monitoring practices and consequently conservation policies (Guisan et al. 2013) and also to prioritise areas for conservation (Carvalho et al. 2011). Species distribution models make use of the limited data available to predict suitable areas for the species to be reintroduced to and consequently survive.

Sometimes both presence and absence occurrence data are available for the development of models, in which case general-purpose statistical methods can be used (for an overview of the variety of techniques currently in use, see Elith, 2002; Guisan and Zimmerman, 2000;
Scott et al., 2002). However, while vast stores of presence-only data exist (particularly in natural history museums and herbaria), absence data are seldom available. This especially applies to poorly sampled tropical regions where modelling has the most potential for conservation (Anderson et al., 2002; Ponder et al., 2001). Therefore species distribution models which require presence only data are particularly valuable (Graham et al., 2004).

Various methods have been used to for presence only modelling of species distributions. One of the methods is BIOCLIM (Busby, 1986), which predicts suitable conditions under bioclimatic envelope, consisting of a region in environmental space representing the range of observed presence values in each environmental aspect (Phillips et al., 2006). DOMAIN (Carpenter et al., 1993) uses a similar metric, but the suitability index is given by calculating the minimum distance to any presence point in environmental space.

Other techniques in place use presence data in addition to background data. General-purpose statistical methods such as generalized linear models (GLMs) and generalized additive models (GAMs) which commonly used for modelling with presence–absence datasets (Phillips et al 2006), have been recently applied to presence only modelling by taking random sample of pixels from the study area known as “background pixels” or “pseudo absences” (Ferrier and Watson., 1996; Ferrier et al., 2002). Environmental Niche Factor Analysis (ENFA) (Hirzel et al., 2002), uses presence localities along with environmental data for the entire study area. ENFA, which does not require a sample of the background to be treated like absences, models suitability as a Manhattan distance in the transformed space. Another method of modelling presence only data is by using Genetic Algorithm of Rule Set Prediction (GARP) (Stockwell and Noble, 1992), which uses genetic algorithms. Used extensively in presence only studies (Anderson., 2003; Joseph and Stockwell., 2002; Peterson and Kluza, 2003), its output is a set of positive and negative rules that altogether gives a binary prediction as compared to a random prediction (Phillips et al. 2006).

2.4.3. Maxent:

Maxent is an all-purpose method for characterising probability distributions from partial information (Phillips et al, 2006). With the origins lying in statistical mechanics (Jaynes, 1957), it is a method that has recently been applied to model species distributions. The method is used to find the distribution of maximum entropy i.e. which is closest to uniform, subject to the restriction that the expected value of each feature under this approximate distribution matches its empirical average (Elith et al.,2006). Maxent predicts a probability distribution based on environmental variables spread over the entire study area. This is also
an approach for dealing with lack of absence data (Hirzel et al., 2002). When constructing the habitat suitability model, the sample points are the occurrence localities of the species, the study area defines the space of the distribution and environmental variables are the features (Phillips et al. 2004). Being a presence only method, Maxent uses randomly selected information from environmental variables, which is used to characterise the features.

The maximum entropy approach to habitat suitability modelling has been applied as the software “Maxent” (Phillips et al., 2005), which can be downloaded freely from the website https://www.cs.princeton.edu/~schapire/maxent/.

Since Maxent is not mature a statistical model as GLM or GAM, there are fewer guidelines for the software as compared to others. Another issue is that of transferability, that been mentioned by Peterson et al, (2007). Although this has been addressed by Phillips (2008b), it needs more testing.

Although other modelling algorithms have been tested more widely in vertebrate species, recent research has demonstrated greater modelling accuracy with Maxent and for limited datasets with sample points less than 25 (Hamel et al 2006; Hernandez et al., 2006; Phillips et al. 2006; Pearson et al., 2007). The Maxent method is among the best-performing modelling approaches for presence-only occurrence data (Elith et al., 2006; Phillips, Anderson & Schapire., 2006).

According to Phillips et al (2004), who compare the use of Maxent against Genetic Algorithm for Rule-Set Prediction GARP, the advantages of using Maxent can be summarised as following

1. In order to make a species distribution model, Maxent requires only presence data together with environmental variables for the entire study area, which is extremely useful when it comes to modelling species distribution for species that do have reliable absence data.
2. Maxent can identify with both continuous and categorical data and can integrate interaction between the different input variables (Gogol-Prokurat, 2011).
3. Over fitting can be avoided by using the regularisation parameter in Maxent, a feature that the other methods do not have.
4. Because there is a clear dependence of the Maxent model on the distribution of the sample data, the issue of sampling bias is formally addressed while making the model.
5. The output is continuous.
6. Rather than discriminative, Maxent is a generative approach, which is an advantage when the amount of training data is limited available is limited or the sample data available is clustered

2.4. Pygmy hog (Porcula salvania)

Pygmy hogs belong to the family Suidae, under suborder Artiodactyla, order Ungulata of class Mammalia. Though it was classified under the genus Sus, recent phylogenetic analysis suggests its classification as a unique genus, Porcula (Funk et al., 2007). They are the smallest and the rarest wild pigs in the world, being listed as critically endangered by IUCN (Narayan and Deka., 2008). It is the smallest suid and is therefore a very valuable genetic resource (Oliver and Deb Roy., 1993). Thus the conservation of the species is of global priority.

The pygmy hog is confined to the tall grass savannah or Terai of the Himalayan foothills and now restricted to northern Assam (Oliver, 1980). These grasslands or mixed "thatch scrub" are a feature of the successional continuum between primary colonising grasses on the new alluvium deposited by changing water courses, through deciduous riverine forests and in drier areas, the Sal (Shea robusta) forest climax vegetation (Oliver and Deb Roy., 1993). More typically, however, they are now maintained by annual (sometimes twice annually) burnings, which has a strong negative impact on the diversity of these habitats and is particularly detrimental to the survival of the pygmy hogs.

A pygmy hog measures about 65 cm (25 inches) in weights and stands 25 cm (10 inches) in height. It approximately weighs from 8 to 9 kgs, a newborn weighing less than 200 grams. Litter size varies from two to six, but is usually three to four (Mallinson 1977; Oliver 1979b). Females are comparatively smaller than the male. Pygmy hogs are often mistaken for the juvenile of a wild boar. What distinguishes a pygmy hog from a wild boar (Sus scrofa) is a vestigial tail (2.5 cm or 1 in adult) and only three pairs of mammae as opposed to six pairs on a wild boar.

Pygmy hogs are omnivores in nature and their diet primarily includes roots and tubers, grass, shoots, insects, fruits, seeds, earthworms and even ground nesting birds, eggs and carrion (Mary et al., 2013). They are habitual foragers spending around six to eight hours actively searching for food, doing so with their snout, digging and turning up litter and topsoil (Oliver, 1980). This leaves a characteristic forage mark, distinguishable from the signs of other species (Mary et al 2013). They are non seasonal nest builders, this behaviour being
unique among all suids (Mary et al., 2013). This nest, made of thatch and other plant material are well concealed and protective against moisture (Oliver 1980).

The main threats to the survival of pygmy hogs are the loss and the degradation of its habitat, the successional grasslands, due to human settlements, agricultural encroachments, flood control schemes and improper management of grasslands (Mary et. al., 2013). Some management practices, such as planting of trees in the grasslands and indiscriminate use of fire to create openings and to promote fresh growth of grass, have caused extensive damage to the habitats the authorities intend to protect.

Figure 2.1. A wild boar is about 10-15 times bulkier than a pygmy hog.

Figure 2.2. Procula salvania in Orang National Park

The pygmy hog is called Nal Gahori in Assamese, Oma Thakri in Bodo and Sano Bandel in Nepali. Assumed to be extinct, the species was rediscovered in 1971 in Manas National Park in Assam and Barnadi Wildlife Sanctuary, form where it has now been extirpated (Oliver 1980). The rediscovery of the species prompted great interest in its conservation management needs, including a series of captive breeding attempts on local tea estates and in the Assam State Zoo and Zurich Zoo, during the 1970s to the early 1980s and in Manas National Park in the late 1980’s, all of this ultimately unsuccessful (Mallinson, 1977; Oliver, 1980; Oliver and Deb Roy., 1993).

Post release monitoring via radio telemetry have been tried on the species since 1989. According to the study by William Oliver in 1989, the author stated that radio telemetry would have been the definite approach to monitoring of the species, because of the elusive nature of the species, the dense habitat and the slim chance of direct sightings. Owing to the
streamlining of the animal’s body, a simple radio collar cannot be applied. Radio harnesses were tried in 1989 but the method was discontinued on account of the loose fit of the harnesses. In the next trial, the method was cancelled on account of abrasions caused on the animals because of the harnesses. Next, radio implants were tried, which too did not succeed. Ear tags were attempted too but because there was a setback, with the antennas breaking before a robust sample of data could be collected. Hence there has been difficulty in developing the tagging methods for the species for radio telemetry and consequently for post release monitoring.

2.5. Former geographic range of the pygmy hog:

According to Hodgson (1847), the species was thought to occur across the Terai range, an extensive area of tall, alluvial grasslands in the foothills of the Himalayas from North Western Uttar Pradesh and Southern Nepal to Assam. Hodgson (1847) also states the possibility of the former habitat extending at intervals into the contiguous habitat in Southern Bhutan, which shares a protected area with Manas National Park in Assam as the Royal Manas National Park.

The species is most certainly extinct over most if it’s known range in the terai and duars region (Oliver, 1991). According to the most recent checklist of the mammals of Nepal (Thapa 2014) the pygmy hog is confirmed to be extinct in the country. Chitwan National Park, Bardia National Park and Sukla Phanta Wildlife Reserve in Nepal were surveyed by Oliver (1985) but the evidence of Porcula salvania was not confirmed. A U.S. expedition from the Hormel Institute spent four weeks looking for the species in 1964. Similarly, in 1978/79, an expedition team from the University of East Anglia also failed to find traces of the animals during a six month survey and hence concluded that it was unlikely that a species survived in the area on account of the restricted remaining suitable habitat (Rands et al. unpubl., 1980). A three month survey in the reserve forests and the wildlife sanctuaries in Bihar, West Bengal and South West Nepal in 1984 were also unsuccessful. There have been no mentions of the species from Bhutan till date. Records are scarce because the species was seldom observed in the wild state, on account of the former inaccessibility of its habitat, to which these animals are extremely adapted by virtue of their diminutive body size, cryptic nature and quick movements (Meijaard. E. pers comm.)
2.6. STUDY AREA

2.6.1 Eastern Himalayan Terai Grassland: Terai Duar Savannah and Grasslands.

The habitat suitability model for the future reintroduction of the pygmy hogs focuses primarily on the Himalayan Terai, which is a continuation of the Gangetic plain. The study area covers Nepal, Bhutan and three states of India namely West Bengal, Assam and Bihar. It includes the Terai Arc Landscape, which constitute the Terai of Nepal, which is recognised as conservation landscape of global importance by various NGOs and scientists (WWF 2000, Wikrama-Nayakes et al., 2004; Sanderson et al., 2006).

Low in elevation, this region is hot and humid in the summer while during the late dry season, the temperature normally reaches 40 degrees centigrade (FAO 1981). The Terai is characterised by fine alluvium and clay rich swamps which support a mosaic to tall grasslands, wetlands and mixed deciduous forests dominated by Sal (Shea robusta) forest. The Terai has been listed among the globally important 2000 ecoregions for the unique Terai-Duar Savannas and the grasslands (Olsen and Dinerstein, 1998), with the alluvial floodplain grasslands being regarded as one of the world’s tallest species.
The area is home to a variety of globally endangered and endemic flora and fauna. Several globally endangered species inhabit the area: the royal Bengal tiger (Panthera tigris), the Great One Horned Rhinoceros (Rhinoceros unicornis), the Asiatic wild buffalo (Bubalus arnee), the Bengal florican (Houbaropsis bengalensis), the hispid hare (Caprolagus hispidus), to name a few. The vegetation is dominated by grasses; low lying wet alluvial grassland and dry savannah, the latter being prime pygmy hog habitat. The typical pygmy hog habitat is said to be dominated by Imperata cylindrica, Narenga porphyrocoma, saccharum spontanuem, Saccharum bengalesis, Phragmitis kharka, Arundo donax, (Shreshta and Joshi, 1997). This region also overlaps with small portions of two EBAs i.e. Central Himalayas EBA in Western Nepal and the far western portion of Assam plains, south of Bhutan (Sattesfield et al, 1988).

The study area also includes the Daur region of West Bengal along with the Terai region, forming the Terai-Duar grasslands. The Duars are essentially slightly elevated alluvial plains (200-500 m above mean sea level), between the Teesta and Sankosh rivers. There formations merge with a narrow Bhabar tract in the north and the central plains (Terai) in the south, covering an area of 5100 km2. The forest vegetation of the Daur is broadly divisible into tropical moist deciduous and tropical semi evergreen forests as per the classification by Champion and Seth (1968). Low alluvial savannah woodlands are represented by tall grasses such as Saccharum spontaeum, Saccharum arundinaceum, Phargmites karka, Arundo donax, Narenga porphyrocoma and Themeda villosa with associations of Khair Sissoo (Acacia catechu- Dalbergia sissoo) and Semul-Siris (Bombax ceiba- Albizia procera) woodlands. This shows similarities in vegetation type between the Terai and the Daur tracts.
2.6.2. Orang National Park:

Within the Terai habitat, the study area for the release of *Porcula salvania* in the 2015 was chosen to be Orang National Park (Ecosystems-India). Located in the state of Assam, India, it covers an area of 78.8 km². The park is located within the geographical limits of 26°29"N to 26°40"N latitude to 92°16"E to 92°27"E longitude. The national park is located in the Darrang and Sonitpur districts of Assam. The altitude of the study area ranges between of 45–75m. Often regarded as an artificially made forest, the park enjoys a floodplain alluvial ecosystem of the Brahmaputra River, which marks the southern boundary of ONP. The complete study area is an alluvial terrace and the entire Rajiv Gandhi Orang National Park could be divided into two halves, i.e. lower Orang and upper Orang. The lower Orang portion is more recent origin, whereas the upper portion to its north is separated by high bank, traversing the park from east to west. The habitat of ONP is composed of wet alluvial grassland (26.06%), dry savannah grasslands (17.97%), with the degraded grassland covering 15.23% and eastern seasonal swamp forest covering 1.72%. About 8.22% of the park is covered by water body and 6.83% is covered by sandy area (Sarma et al., 2011).
Figure 2.5: Orang National Park
CHAPTER 3: METHODS AND MATERIALS

3.1. Radio tracking pygmy hogs in Rajiv Gandhi Orang National Park in Assam, India:

Radio tracking method: A cohort of nine captive bred pygmy hogs were released in two batches of five and four individuals respectively in two pre chosen release sites, 1.5 km from each other (Figure). The two social groups were released within a gap of 5 days. Four pygmy hogs (two in each social group) were tagged using ear transmitters post release. Four of the transmitters were modified from the ones used in the previous year produced by Biotrack. Four radio transmitters were placed on the ears using ear tags which had slightly thicker depth of dental acrylic on the side. Two of the tags had NiTi antennae (0.2mm) with a rubber sleeve and a cone at their point of exit to minimise stress. Two tags had shorter 40 g antennae (one horizontal and one vertical). All the transmitters had a longer pulse length to improve the range, which reduced the battery life from 9 to 6 months). The orientation of the components of the tags was changed so that the battery sat below the transmitter components (Delahay, R, pers. comm.). The receivers were connected with a hand held three element Yagi type antenna.

A minimum of 2 directional bearings from different locations were used to determine the location of each individual, using a hand held magnetic compass. The bearings were taken approximately 90 degrees from each other (Millsbaugh and Marzluff 2001; White and Garrot 1990). This was executed using Garmin MapSource. Significant effort was made to reduce the time between each record taken so as to reduce error and bias. The radio location positions were recorded each day in the morning, afternoon and the evenings and the time between the two social groups were divided on a rotational basis. Unfortunately, the antennas of the radio transmitters failed to work 10 days into the release on account of the antennas of the radio transmitters breaking. No further analysis investigating habitat use or movement patterns of the species could be carried out because of the small sample size of the location data.

The triangulated areas were located on the map, the coordinates entered in the Garmin eTrex and the individual points visited on elephant over 3 days. At the locations, the grassland type, the habitat composition and elevation of the area was recorded around a 5 m radius. Additionally, the areas were scanned for signs of pygmy hog habitation (secondary signs i.e. pellets, foraging marks, nests).
Table 3.1. Details of social group 1 of released individuals

<table>
<thead>
<tr>
<th>S.No</th>
<th>Sex</th>
<th>Life Stage</th>
<th>Date of release</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Male</td>
<td>Young adult</td>
<td>20-May-2015</td>
<td>Tagged</td>
</tr>
<tr>
<td>2.</td>
<td>Female</td>
<td>Sub-adult</td>
<td>25-May-2015</td>
<td>Tagged</td>
</tr>
<tr>
<td>3.</td>
<td>Female</td>
<td>Sub-adult</td>
<td>20-May-2015</td>
<td>Untagged</td>
</tr>
<tr>
<td>4.</td>
<td>Female</td>
<td>Sub-adult</td>
<td>20-May-2015</td>
<td>Untagged</td>
</tr>
<tr>
<td>5.</td>
<td>Male</td>
<td>Sub-adult</td>
<td>20-May-2015</td>
<td>Untagged</td>
</tr>
</tbody>
</table>

Table 3.2. Details of social group 2 of released individuals

<table>
<thead>
<tr>
<th>S.No</th>
<th>Sex</th>
<th>Life Stage</th>
<th>Date of release</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Female</td>
<td>Sub-adult</td>
<td>25-May-2015</td>
<td>Untagged</td>
</tr>
<tr>
<td>2.</td>
<td>Female</td>
<td>Sub-adult</td>
<td>25-May-2015</td>
<td>Untagged</td>
</tr>
<tr>
<td>3.</td>
<td>Female</td>
<td>Young adult</td>
<td>25-May-2015</td>
<td>Tagged</td>
</tr>
<tr>
<td>4.</td>
<td>Female</td>
<td>Young adult</td>
<td>25-May-2015</td>
<td>Tagged</td>
</tr>
</tbody>
</table>
Figure 3.1: The radio transmitter that was utilised for the release of 2015 (Picture by Himagshu Gogoi, Ecosystem-India)

Figure 3.2. The map showing the release area chosen by the PHCP and the release sites
3.2. Data procurement of updating the map for the historical presence of pygmy hogs

The first method that was used to procure data for the historical presence of the pygmy hogs was to collect and read through old literature and field notes. This was carried out by searching for books and articles from online databases such as the Biodiversity Heritage Library (http://biodiversitylibrary.org/) and the Internet Archive (https://archive.org/index.php).

Another method that was used was to contact natural history museums through emails and personal visits. Fifty natural history museums were individually contacted globally. Emails requesting information or records of pygmy hog specimens and location data were also sent to the NATSCA who are a UK based membership organisation that represents natural science collections. Data for pygmy hog specimens were also searched for in online databases such as VertNet (http://portal.vertnet.org/search), GBIF (http://www.gbif.org/) and MaNIS (http://manisnet.org/). For the historical presence locations obtained from field notes, the coordinates for those areas were confirmed by georeferencing U.S Army Map Service Topographic Maps. This was carried out using QGIS 8.2.1.

The final updated map of the distribution of the pygmy hogs was produced using ArcGIS 10.2.

3.3. Maxent modelling:

3.3.1. Selection of the study area

The study area that was chosen for the prediction of potential suitable habitat for the Maxent model was chosen to represent the historical range of the species. This was designated on the basis of the records of the former distribution of pygmy hogs, collected during the study.
Figure 3.3. Overview of the complete protocol used in this section of the study.

### 3.3.2. Presence data:

The sample data that was used to parameterise the model was the data that was collected by Ecosystem India, from 2010 to 2015. The points that were used for the study were sightings data from the three protected areas where the pygmy hogs are found at present i.e. Manas National Park, Sonai Rupai Wildlife Sanctuary and Rajiv Gandhi Orang National Park, all of which are located in North-West Assam. On account of the rarity and the elusiveness of the species, none of the points were direct sightings, but rather secondary sightings i.e. evidence of pellets, foraging marks, nests (burnt, fresh and degraded) (pictures in the appendix).

The position of each of the sighting of pygmy hogs sign was recorded with a GPS, Garmin eTrex. All the data was projected to UTM (Universal Transverse Mercator) coordinate system (zone 46N) with datum WGS84 and stored as shapefiles (.shp) for further use.

### 3.3.3. Processing of the sample data

337 presence points of the pygmy hogs were recorded in total, over the last five years. The points were particularly clustered, with more than 9 points in one pixel (94.5m) in some instances. Biased datasets, due to observer effort being focussed in particular areas, can lead to artificial clusters of observation, which consequently violate the assumption of independence (Dormann et al. 2007). This can be alleviated by sampling one point per
cluster in environmental space. (Varela et al., 2009; Stiels et al., 2011). Therefore to avoid spatial correlation, the points were filtered so that not more than one point fell in one pixel. This was carried out using ArcGIS 10.2. The sample dataset was reduced from an initial number of 337 points to 174 points, which was used to build the model.

### 3.3.3. Environmental layers for the habitat suitability model

Seven variables were chosen as potential predictors of the *P. salvania habitat* distribution. These variables were chosen based on their biological relevance to pygmy hog distribution. A key reason was also the availability of the data, as there is very less, high resolution data available for the particular region. To capture land cover, a map was obtained from the Moderate Resolution Imaging Spectroradiometer (MODIS); land cover map (version 5.2). This land cover map is derived from annual time series of reflectance images, vegetation indices and land surface temperatures from the MODIS satellites at a spatial resolution of 500 m. The 2010 map with the International Biosphere-Geosphere Programme legend was procured that comprises 16 classes (10 vegetation classes, 3 developed and mosaic land classes and 3 non vegetated land classes). As additional continuous measures of land cover and the vegetation, grids of percent tree, herbaceous and bare ground cover from the MODIS Vegetation Continuous Fields product was obtained from the Global Land Cover Facility (GLCF), University of Maryland (http://glcf.umbc.edu/data/vcf/) website.

To characterise human disturbance, distance to roads was considered. The Euclidean distance was calculated using ArcGIS 10.2. Population density was also considered to characterise human disturbance. Data on global wetlands was obtained from Global Lakes and Wetlands Database. The Euclidean distance was calculated as the distance to roads. Elevation data was obtained from the Shuttle Radar Topography Mission (SRTM) elevation model. The elevation data was used to generate slope (in degrees) using ArcGIS 10.2. The variables were tested for autocorrelation using ArcGIS10.2.

The selected variables were projected to Universal Transverse Mercator Zone 46 (UTM 46N) and were all resampled to the same extent and pixel size as the elevation file (pixel size of 94.5m).
Table 3.1. The predictor variables used in the Maxent model and the individual resolution prior to resampling

<table>
<thead>
<tr>
<th>Layer Name</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation</td>
<td>Shuttle Radar Topographic Mission 30 arc seconds</td>
</tr>
<tr>
<td>Distance to roads</td>
<td>SEDAC; Global Roads Open Access Dataset 2.5 arc minute</td>
</tr>
<tr>
<td>Distance to wetlands</td>
<td>Global Lakes and Wetland Database 30 arc seconds</td>
</tr>
<tr>
<td>Landcover</td>
<td>MODIS (MCQ12I) 500m</td>
</tr>
<tr>
<td>Vegetation Fields</td>
<td>Continuous Global Land Cover Facility, <a href="http://www.landcover.org">www.landcover.org</a> 250m</td>
</tr>
<tr>
<td>Slope</td>
<td>Calculated from SRTM using ArcGIS 30 arc seconds</td>
</tr>
<tr>
<td>Population density</td>
<td>SEDAC; Population density grid 2.5 arc minute</td>
</tr>
</tbody>
</table>

3.3.4. Habitat Suitability Modelling

Maxent software (version 3.3.3) was used to generate the habitat suitability model. Recommended default values of convergence threshold (0.00001), maximum number of iterations (500) were used when building the model (Phillips, 2008a). The model was replicated 15 times and the resultant model used was an average. To estimate variable importance, jackknife tests were run, excluding each variable in turn then creating models with each variable in isolation.

Maxent, like other presence-pseudo-absence methods, generates background or pseudo-absence sample points (Elith et al., 2011), by which 10000 random points are selected from the whole study area. However, according to (Phillips 2008a), when occurrences are restricted to a fraction of the study area, as it is in the case of the pygmy hog, model performance can be enhanced by drawing background points from the particular fraction of the area, improving the reliability of predictions when transferred to the rest of the region. Taking this into account, 10000 pseudo absences were randomly sampled from buffer areas around the sample points. A radius of 20 km was constructed around the sample dataset. This particular area was chosen taking into account the approximate suitable release area in...
ONP (shown in Figure), which was selected by Ecosystems-India. The buffer was constructed using SDMToolbox (Brown, 2014).

3.3.5. Model Selection and habitat suitability map

Test figures were obtained for each of the models compared, reserving a randomly selected set for the test data (25%); 75% training data. Test AUC is preferred over training AUC since a model predicting the test sample reflects its capacity to generalise better (Phillips, 2008). The final model was chosen on the basis of the AUC value of the test data (Austin, 2007). A map of the habitat suitability was finally produced based on the selected model.

From the selected model, a logistic map as well a binary map was obtained. For the binary map, 10 percentile training presence logistic threshold of 0.3234 was used, the values above which is depicted as suitable (Pearson et al. 2007; Kumar et al 2009)

3.3.6. Selection of the conservation priority areas

The final map obtained from the selected Maxent model was overlaid with a map of protected areas obtained from the World Database of Protected Areas (http://www.protectedplanet.net/). The protected areas falling over the suitable habitat for pygmy hogs were identified. The area of the suitable habitat was calculated using ArcGIS 10.2.
CHAPTER 4. RESULTS

Results are organised in order of ascending scale of analysis, towards a better understanding of the factors affecting the reintroduction success of pygmy hogs as a key component of the conservation strategy for the species. I start with the detailed analysis of the 2015 reintroduction, followed by the mapping of former habitat and development of the Maxent model. This leads to an analysis of areas of suitable habitat for pygmy hogs, and recommendations of suitable sites for future reintroductions.

4.1. Results of radio tracking the pygmy hogs in Orang National Park

The radio tracked data collected for the four tagged individual consisted of 26 points in total. From the sparse data collected, it was found that the pygmy hogs travelled a maximum of 5 km (one individual) from the release site within the 10 days that they were radiotracked. It was also observed that the individuals inhabited the same habitat type i.e. the dry savannah grasslands, with *Imperata cylindrica*, *Narenga porphyrocoma* and *Saccharum spontaneum*, *Arundo donax*, being the major species of grasses that were recorded. The grasses were interspersed with *Bombax ceiba*, *Curcuma zedoaria*, *Ziziphus Maura*. The grass height recorded was from a range of 7ft - 10ft. The points located were on an elevation of 60m to 67m above mean sea level. (Data collection sheet included in the appendix)

Some secondary signs of the pygmy hogs were found around the areas where the points were triangulated that were of a foraging mark and two encounters of pellets. The less presence found could be because the grassland was waterlogged in some areas on account of heavy rainfall before surveying. That was indication that the animals had inhabited the areas. It also made a link between the types of data collected by Ecosystems-India to infer pygmy hog presence and actual presence based on radio tracked data.

Unfortunately, no further analysis could be carried out on account of the data being insufficient to estimate the habitat use.
Figure 4.1 Location points recorded for Porcula salvania post radio tracking and triangulation
4.2. Historical distribution of *Porcula salvania*:

From the methods applied, historical records the pygmy hogs were found in the following areas from its former range, with addition of entirely new records of the species discovered.

**India**: The type specimens of *Porcula salvania* in most of the literature is from Sikkim Terai (Hodgson 1847a). Because of its rarity and the elusiveness, there are very few specimens and records of the species (Lydecker 1990). Since India does not have terai habitat, it may be assumed that the specimens that were found in the Sikkim terai was were actually from the Duars in West Bengal, with which Sikkim shares a border with and which also has a range of grasslands. An account by Jerdon (1847) states that the author searched for the pygmy hog in the Sikkim Terai while at Darjeeling, which is a state in West Bengal, which supports the assumption.

From the database VertNet, three specimens were procured from India, although the exact locality and the coordinates were not mentioned. Apart from the aforementioned areas, a new record was found from the country. The Yale Peabody Museum of Natural History houses a specimen of pygmy hog from the state of Bihar, from where no records of the species have been found before. The collector of the specimen was Hodgson (1847).

Though in the literature, the species have been stated to occur historically in Uttar Pradesh, no records have been found to confirm the presence of pygmy hogs from this particular state in India, from this study or from any previous literature. Uttar Pradesh does have a tract of Terai grasslands, though it is difficult to say if the areas are pygmy hog suitable or not due to no surveys for pygmy hog suitability conducted before.

**Bhutan**: The only early historic reference of pygmy hogs from the country was from Pollok and Thom (1900) who mentioned the species as being found in the ‘Dooars from the base of the Bhutan Hills’. The information is insufficient to deduce which particular area they are referring to. Bhutan as a country houses a very small range of Terai, in the Royal Manas Wildlife Sanctuary which is contiguous with the Terai of Manas National Park in Assam (India). From the study, two new specimens were discovered from Bhutan. The National Museum of Ireland responded positively with two specimens of the species from the country. Unfortunately, there was no information regarding the exact location of the collection. However, this is the first confirmed record of the species that has been found from the country of Bhutan.

**Nepal**: Three references to the species were procured from this country by referring in Fleming 1964). The author states that he comes across nine pygmy hogs in Dhanghari
district of Nepal. There have also been mentioned to have observed in Kailali, Kanchanpur and Kaneri district of Nepal, although the narrative is not clear to determine the accuracy of the information. According to Jnawali et al (2011), the species was last reported in the 1970s from Trijuga, Koshi Taapu Wildlife Reserve and Chitwan National Park. There is also a possibility of the species having been occurred in Bardia National Park and Shukla Phanta Wildlife Reserve, although this could not be proved (Jnawali et al. (2011).

Four natural history museums reported references of the species from the country. Hence it can definitely be deduced that the species did in fact occur in Nepal historically. An updated map of the range of the species constructed with the procured information using ArcGIS 10.2.

![Figure 4.2. Updated map of the historical distribution of Porcula salvania](image-url)
4.3. Results of the Maxent model:

4.3.1. Maps of suitable habitat:

Habitat suitability models were created for pygmy hogs across the Terai range from occurrence data collected between 2010 and 2015. The final model was chosen on the basis of the AUC value of the test data (25% of the data). The AUC value was greater than 0.9, indicating the model performed better than a random model would and the model has a good robustness to false positives (Thuiller et al., 2003). Swets (1988) have established a scale to enable interpretation of AUC values and for model validation: 0.90-1.00 = excellent; 0.80 to 0.90 = good; 0.70 to 0.80 = average; 0.60 to 0.70 = poor; 0.50 to 0.60 = insufficient.

Figure 4.4. Graph of the Area Under the Receiver Operating Characteristic (ROC) Curve or AUC
4.3.2. Variable importance:

Figure illustrates the results of the jackknife test or variable importance using test data. The information each variable provides to the model can be assessed by the model gain (“with only variable” bar), variables providing least information will result in a poor model gain and a small "with only" bar. For this model, population density provides the most information as a single variable, followed by elevation and continuous vegetation field index. As compared, distance to wetlands and slope seems to have the least effect on the model.

Once the best model was selected, the last step in the process was to create a map of the habitat suitability based on the model trained with the available pygmy hog presence samples. Maxent’s output map can be displayed in several output formats (Phillips et al 2008, Phillips 2008). The easiest to interpret is the logistic format, which gives an estimated index of habitat suitability.

The figure below shows the Maxent logistic map of habitat suitability created with the final set of variables.
The HSI map predicted by the final model showed widespread potential suitable pygmy hog habitat across the species historical range (Figure). Large habitat patches were mainly clustered in the grasslands of the state of Assam in India. The final model also assigned high suitability values in the pygmy hog strongholds, such as the Manas National Park and other potential reintroduction sites that were identified by the Pygmy hog conservation programme i.e Sonai Rupai Wildlife Sanctuary and Rajiv Gandhi Orang National Park.

It is generally better to avoid binary prediction maps (suitable/unsuitable), unless the model is well calibrated (Wintle et al. 2005). If such a map is required, a threshold must be selected, above which the area is deemed suitable. Maxent calculated threshold based on the training data and the ROC curve. For this model, 10th percentile training presence logistic threshold of 0.3234 was selected, an average of the replicates. Shown below is the binary prediction map of the Maxent model.

Figure 4.6. Logistic map of the suitable habitat across the terai range
Figure 4.7. Binary prediction map; suitable/unsuitable

4.3.3 Selection of conservation priority areas:

Once the model was finalised, the map was overlaid with a map of protected areas obtained from the World Database of Protected Areas. Protected areas were identified from this as potential areas for surveying for habitat suitability for further reintroductions. A total of fifteen protected areas have been identified as priority survey sites in across the former range; eight in India, and six in Nepal. (Table).

From the habitat suitability map procured, there were no suitable areas that were identified in the country of Bhutan and the state of Bihar, from where historical presence data was obtained from the previous section of the study.
Figure 4.1. Habitat suitability map overlaid with a map of protected areas to identify areas as potential survey sites.
*protected areas where the current population of pygmy hogs exist

Table 4.2. Protected areas identified as potential survey sites in India and Nepal

<table>
<thead>
<tr>
<th>S. No</th>
<th>Protected Areas</th>
<th>Country</th>
<th>State/ District</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Manas National Park*</td>
<td>India</td>
<td>Assam</td>
</tr>
<tr>
<td>2.</td>
<td>Orang National Park*</td>
<td>India</td>
<td>Assam</td>
</tr>
<tr>
<td>3.</td>
<td>Sonai National Park*</td>
<td>India</td>
<td>Assam</td>
</tr>
<tr>
<td>4.</td>
<td>Nameri National Park</td>
<td>India</td>
<td>Assam</td>
</tr>
<tr>
<td>5.</td>
<td>Kaziranga National Park</td>
<td>India</td>
<td>Assam</td>
</tr>
<tr>
<td>6.</td>
<td>Dibru Saikhowa National Park</td>
<td>India</td>
<td>Assam</td>
</tr>
<tr>
<td>7.</td>
<td>Gorumara National Park</td>
<td>India</td>
<td>West Bengal</td>
</tr>
<tr>
<td>8.</td>
<td>Jaldapara Wildlife Sanctuary</td>
<td>India</td>
<td>West Bengal</td>
</tr>
<tr>
<td>10.</td>
<td>Bardia National Park</td>
<td>Nepal</td>
<td>Bardiya</td>
</tr>
<tr>
<td>12.</td>
<td>Shukla Phanta Wildlife Reserve</td>
<td>Nepal</td>
<td>Kanchanpur</td>
</tr>
<tr>
<td>13.</td>
<td>Parsa Wildlife Reserve</td>
<td>Nepal</td>
<td>Makwanpur and Bara</td>
</tr>
<tr>
<td>15.</td>
<td>Banke Buffer Zone</td>
<td>Nepal</td>
<td>Banke</td>
</tr>
</tbody>
</table>
CHAPTER 5. DISCUSSION

This study set out to evaluate the short term success of a reintroduction as part of the Pygmy Hog Conservation Programme as well as to investigate the historical distribution of the species thereby informing the production of a habitat suitability map. Using information from the last 5 years of pygmy hog habitat use, this model was used to identify areas to be targeted for the reintroduction of *Porcula salvania* across its former range, where it no longer exists. This is the first study to attempt to evaluate these aspects of the Pygmy Hog Conservation Programme in depth and also the first to confirm the historical distribution of the species after the study by William Oliver in 1989, updating the IUCN range map. These confirmed records were used to select sites for the species distribution model formulation and for recommended future reintroductions.

The following sections hence draw lessons from this work and discuss ways forward in terms of additional data that could be used to enhance the model. This study is then put in context of improving reintroduction programmes of rare species, in the short term and in the long term, both for pygmy hogs and more generally.

5.1. Evaluating the short term success of the reintroduction programme

Although this study was able provide some information about habitat use of the released individuals immediately post release, the study still failed because there was a problem with the radio transmitters that were put on the individuals. Just a few days post release, the antennas of the transmitters broke from their base. Since ear tags and radio harnesses, which have antennas have not worked before, it would appear that the main problem with the species have been that of the antennas. Since the grasslands are dense and sharp and the animal’s quick in their movements, there has been a general difficulty in keeping the antennas intact. Finding the appropriate technology and tracking methods for species that have difficult body morphologies has been a challenge in reintroduction programmes. Zschille et al, (2007) discuss the failures and shortcomings in radio tagging the American mink (*Mustela vison*), using radio collars and intraperitoneal implants.

Even though there are other methods of telemetry i.e. satellite and GPS, radio telemetry has offered the only practical means for monitoring animals of relatively small body size inhabiting dense vegetation habitats for which direct sightings would not be a possibility, except that by chance (Narayan and Deka, 2008). There is also a question of the cost. Hence, only once the method of tagging is established, can the other methods be applied.
Another setback in the pygmy hog reintroduction programme has been in the actual data collection, with no set data collection till date.

Since the tagging methods are still in work, there is a need for the development of other forms of monitoring the species. So far, sign surveys that have been conducted have so far been successful and have been a good estimation of habitat use of the species. However, the monitoring needs to be more systematic in its design and implementation.

It is important to standardise effort, so that observation error does not contaminate the dataset. Camera traps appear to be the next best form of monitoring as direct sighting of the species is near to impossible. This has been conducted by the PHCP in the past, setting up traps near nests of pygmy hogs. Strategic placement of cameras would be recommended based on prior knowledge of the species biology.

Participatory monitoring is a good way of engaging local people in the management of the resources and also generating valuable ecological knowledge (Danielson et al, 2007, 2009). Cost effective and sustainable, this would be a good way for the PHCP to increase manpower and also generate a sense of responsibility among the local people. However, the design would have to be well designed to avoid biased estimates and would require training of the local people in observing the species as well as educating them about the behaviour of the species in question in detail (Kindberg et al., 2009).

Another method that could be implemented is that of using surrogate or sympatric species in monitoring and also in tagging methods. Relatively abundant, closely related species are sometimes used as surrogates in refining tagging methods or testing the suitability of methods before transfer to rare and threatened species (Ebner et al., 2009). Ebner et al (2009) utilised this method to radio track a species of fish, using an abundant species as a surrogate to trial the radio tagging method. Although this method was not a success in their study, this method may be trialled in the pygmy hog’s case using hispid hare, with which pygmy hog share sympatric associations with (Mallinson.,1971; Tessier-Yandell., 1972).

Until a reliable method of tagging pygmy hogs is established, the programme will remain challenged. Till then, other forms of monitoring the species may be looked into. However, there is a general dearth of reporting of failures in reintroductions (Sarazzin and Barbault, 1996), which urgently needs to change. Proactive learning from both successes and failures is required, especially in order to conserve rare and endangered species.
5.2. Use of historical presence data as a conservation tool in reintroduction programmes:

The current design of reintroduction programmes is hampered by our partial knowledge of the geographic distribution of species (Lomolino 2004, Whittaker et al 2005). This is the case with the pygmy hog reintroduction programme, where there is partial or an approximate knowledge of the species across the former rang.

Keeping in mind the dynamic nature of habitats, expanding in some regions while lessening in others over time or logistic or political constraints (Hengeveld, 1990; Graham et al. 2004), it would questionable to use historical presence data to directly inform reintroduction of species. This is particularly true for the ever changing Terai grasslands, with its successional nature and also with the boom of agriculture and hunting over the last five years. Even though historical perspectives have been increasingly used to complement field surveys (Ponder et al 2001), there is many a spatial error accompanied with the data. Some of them may be georeferencing errors or error in the original records. Also historical presence may include some bias in terms of how the data has been sampled i.e. along roads and rivers, near towns or accessible areas (Hijmans et al., 2000). For the pygmy hogs, data were biased to a certain extent in terms of the data collection as most of the suitable habitat was inaccessible on account of the density of the grassland and the safety concerns attached. Hence, most of the data collections were from that along roads and sometimes approximately 500 m into the grassland on elephant back. However, most of the sign surveys that been conducted till date have been post burning (February to March), when the grass height is relatively low. There is still difficulty in accessing areas that are deep in the grasslands.

However, completely new records of the species were found, that broadens our knowledge of known range of the species. This method used in the study could be used for similar rare and cryptic species that have a general dearth of presence data to them.

5.3. Identifying likely suitable reintroduction sites:

This study utilised data collected from three national parks in Assam, out of which two are reintroduced populations i.e. Sonai Rupai National Park and Orang National Park. This was done on account of less data being available from Manas National Park to construct a model and extrapolate across the entire former range. There may be a question of bias as to question the suitability of the latter areas for the pygmy hogs. Studies were conducted prior to reintroductions to compare the habitats of the original and the other national parks, which cuts back some form of bias.
As indicated in the review by Chape et al., 2005, there are certain inaccuracies in the current spatial data on the World Protected Area Database, which means there might be a certain imprecision in identifying conservation gaps and defining priorities. Hence, careful of the model by experts can be done by using regional maps of protected areas to identify the protected areas which are not covered by database.

Of the variables available and used, slope, distance to wetlands, and the land cover were found to be least explanatory while distance to roads, elevation and the continuous vegetation field were identified as explanatory. From this a number of conclusions can be drawn.

Previous studies have thought the pygmy hogs to prefer relatively lower areas (Deka, P, pers comm), as shown in the model, where a majority of the areas, there was a positive relationship to elevation to habitat suitability.

The exclusion of slope was an indicator of the species suggestions that the species may not prefer slopes but the grasslands that remain upon them, which is indicated in the model more by elevation and the vegetation continuous field data.

Distance to roads and the population density seem to have particular importance to suitable habitat of the area to pygmy hogs. The distance of roads may be accountable because of the proximity of the national parks from where the training data is particularly from. Also, most of the national parks identified from the model are at a distance from the major roads.

The population density may be considered a proxy for hunting or also agricultural practices, which are both human disturbances. Saying so, hunting of pygmy hogs haven’t been reported as being one of the major reasons of pygmy hog decline for the last few years (Oliver, 1991).

It’s very interesting how distance to wetlands hasn’t shown much importance in terms of suitability to the pygmy hog. A reason for this may be the abundance of wetlands in Terai habitat that it may not be as dependant on them as thought (Jha et.al.,2009).

Pygmy hogs were last reported from Chitwan National Park and Kosi Taapu in the 1970s by Jnawali et al., (2011), an area which shows high suitability according to the Maxent model. The model also shows considerable suitable habitat in the state of West Bengal. This shows that there is some consistency with the historical range of the species.

The habitat suitability model shows considerable suitable habitat in the extreme east of Assam, which houses Dibru Saikhowa National Park. This park consists more of the wet alluvial grassland habitat than the dry savannah type grassland (Choudhury,2002), which
pygmy hogs are more accustomed to. There have been no records of the species in this area of Assam before. However, there is an overlap in the species of grassed between this particular national park and the pygmy hog strongholds (Choudhury, 1998). (Medhi, 2010, unplub; Lakhar, 2009, unpub).

5.4. Research and conservation recommendations:

Knowledge of habitat suitability is particularly important for the conservation of the critically endangered species like the pygmy hog. Pawar et al., 2007 provide an example of habitat modelling with Maxent coupled with conservation planning at a regional scale in a developing country.

A detailed exploration of the map with local or regional experts would be recommended which might reveal gaps and opportunities in the conservation of the pygmy hog. The next step would be to assess on the ground if the areas are indeed suitable for the species or if the areas require habitat restoration prior to reintroduction.

Taking into account the dynamic nature of the Terai belt, another recommendation would be to repeat the protocol of the habitat suitability model with survey data of the coming years to encompass the evolution of the ever changing grasslands. Since this particular study area does not have any regional landcover maps, it would be worthwhile to prepare some, with satellite imagery improving in quality and accuracy day by day. This would yield more accurate results in terms of the habitat usage and also may be used in monitoring of the species, which is urgent in need.

According to Osborne and Seddon (2012), one of the most important uses of HS models is to predict habitat suitability in the future. There have been various studies that have built SDMs based on climate data and that have forecasted the impacts of climate change by inserting future climatic variables from the Intergovernmental Panel on Climate Change (IPCC) projections. Synes and Osborne (2011) modelled suitable climate species in Europe for the great bustard (Otis tarda) in Europe for the year 2020 and 2080 using this method. This method can be refined further by considering land use change in addition to the effects of climatic variables (Wisz et al., 2008).

A more detailed research into what threats that caused extirpation of the species across the former range would be desirable, especially in the different countries and areas as the types and the level of threats vary across areas. For example, in Assam, where in depth study on the pygmy hog has been conducted, the threats to the grasslands and consequently the pygmy hogs are known. Surveys could be conducted in the areas identified in the map to assess threat levels and target those areas for habitat restoration and management.
In conclusion, the national parks and the sites that were selected from the habitat distribution model predict highly suitable areas for the pygmy hogs across its former range. In order to boost numbers across its former range, the next step would be to conduct extensive evaluations of these sites to establish the areas as potential release sites or sites that need to be restored prior to the reintroducing these critically endangered species.
References


Jerdon, T. C. (1874) *The mammals of India: a natural history of all the animals known to inhabit continental India*. J. Wheldon.


Annex A: Pygmy hog secondary signs

Pygmy hog pellets
Credit: Parag J. Deka, Ecosystems-India

Pygmy hog foraging mark
Credit: Parag J. Deka, Ecosystems-India
Pygmy hog nest
Credit: Parag J. Deka,
Ecosystems-India
Annex 2: Grassland of Orang National Park
Annex 3: Radio harnesses previously used on the pygmy hogs

Fig. 4. Radio tracking harness design. The harness contains twin feeder cables, which serve as antennae, as well as providing tensile strength; the free ends of each strap/antenna loop were cut to size in the field and secured with small bolts to the transmitter capsule.