25 Year Bengal Fox (*Vulpes bengalensis*) Management Plan for Karnataka, India

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Spring 2022

Submitted: April 2022

A paper submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Fisheries and Wildlife Sciences, Wildlife Concentration, at Paul Smith's College

Executive Summary

Bengal foxes (*Vulpes bengalensis*) are a small canid endemic to India and adjacent regions. They are opportunistic omnivores, consuming a wide variety of food-items which may vary in abundance seasonally and/or spatially. Conservation issues of primary concern include habitat loss, habitat degradation, poaching, and outbreaks of enzootic diseases. Space needed to accommodate the growing human population as well as increases in agricultural and industrial output has led to encroachment of humans onto Bengal fox habitat. This management plan aims to increase Bengal fox populations within Karnataka, India to ~10,000 individuals to allow grazing and development practices to continue. Objectives to reach this goal include estimating and mapping habitat suitability in Karnataka, performing a mark-recapture study to gain information on population dynamics, providing public education on Bengal fox conservation to residents and ecotourists, and increasing the survivorship of pup and juvenile age classes. To estimate habitat suitability, vegetation will need to be surveyed throughout Karnataka using a series of randomly generated plots. Measurements of habitat suitability will be compiled in a map utilizing ArcGIS which will help locate areas with potentially high Bengal fox densities. A mark-recapture study will be executed to gain knowledge on survivorship of the Bengal fox population in Karnataka. A Cormack-Jolly-Seber Model will be utilized to interpret survivorship of the Bengal fox population following the mark-recapture study. Data on current Bengal fox population dynamics is lacking from the literature and is necessary for the needs of this management plan as well as future studies on Bengal foxes. Public education of Bengal fox conservation will take place in public schools and various ecotourist destinations to help identify uncertainties and biases in knowledge. The distribution of surveys will evaluate public awareness and perceptions of Bengal fox conservation needs in Karnataka after public education initiatives have been implemented for multiple years. Community support and involvement will be crucial in minimizing poaching events and overgrazing of Karnataka's grasslands. Survivorship of pup and juvenile age classes will be increased through the restoration of habitat, discontinuation of overgrazing, and declaration of Karnataka as a "Closed Area". Local communities will qualify for incentives gained from revenues of localized protected areas to discontinue harmful grazing practices and allow habitat restoration to occur on their lands. By declaring Karnataka, a "Closed Area", hunting of local wildlife species would be banned but development projects and overgrazing practices could continue. Therefore, public support of this management plan must be gained for conservation to be successful. Implementation of this management plan will potentially raise the Bengal fox population of Karnataka, India to ~10,000 individuals for the benefit of their ecosystem and the local ecotourism industry.

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Introduction

Bengal foxes (*Vulpes bengalensis*) are a species native to India and regions immediately adjacent (Jhala and Johnsingh 2004). They are small canids that are related, sympatric, and similar to red foxes (*Vulpes vulpes*), though the black-tipped tail of Bengal foxes is a distinguishable feature used for identification (Gompper and Vanak 2006). Their preferred habitat consists of short, semi-arid grasslands (Vanak 2005), which are located along the west coast and south-central regions of India. As opportunistic omnivores, Bengal foxes exploit multiple food sources including insects, rodents, reptiles, birds, and fruits (Jhala and Johnsingh 2004). Unlike many canids, Bengal foxes rarely scavenge for carcasses (<1% of diet) or depredate livestock (Bopanna et al. 2012; Srivathsa et al. 2019). Survival of offspring during and after the spring pup-rearing period is crucial for Bengal fox populations due to their small litter sizes (2.7) and short lifespan (8-10 years) (Jhala and Johnsingh 2004).

The Indian Wildlife (Protection) Act lists Bengal foxes as a Schedule II (part II) species which affords them little protection (Bist 1999; Vanak 2005). Their current scheduling in India results from an unwieldy and unstable classification system which is not based on scientific standards (Bist 1999). Bengal foxes face continued threats, mainly imposed by the increasing human population, India's current economic growth, and the persistence of historical perspectives of grasslands. Major threats to the species include habitat loss through overgrazing by pastoralists, land-use alterations, spread of invasive plant species, and urbanization as well as poaching events by rural and tribal communities and disease outbreaks spread by domestic dogs (*Canis familiaris*) (Jhala and Johnsingh 2004; Gompper and Vanak 2006; Srivathsa et al. 2019). Throughout their range, Bengal foxes only occur in high population densities when occupying semi-arid grasslands and shrublands (Jhala and Johnsingh 2004; Vanak 2005). Although large tracts of grassland are rare and typically privately owned in peninsular India, some protected grassland areas exist in the state of Karnataka, including the Ranibennur Blackbuck Sanctuary and Jayamangali Blackbuck Reserve (Vanak 2005; Gompper and Vanak 2010). However, Bengal fox habitat in semi-arid grasslands and shrublands accounts for less than 2% of protected areas in southern India (Vanak 2005).

Populations are difficult to locate and quantify because Bengal foxes are predominately nocturnal, wary of humans, and avoid anthropogenic development (Gompper and Vanak 2006; Chellum et al. 2013). To locate potential populations in Karnataka with limited current data, a habitat suitability analysis will be performed over multiple years, with results modeled using ArcGIS software. To gain information on the survivability of the Bengal fox population in Karnataka, a mark-recapture study must be implemented over multiple years. Hunting and parts trade of Bengal foxes by rural communities and native tribes continues despite current policy which prohibits these activities (Bist 1999; Jhala and Johnsingh 2004;

Gompper and Vanak 2006). Additionally, government initiatives support both the destructive grazing practices exhibited by traditional pastoralists as well as the land clearance and development programs which aim to urbanize semi-arid grasslands (Vanak et al. 2013; Kapuria 2021). To combat both poaching and harmful grazing practices, public education initiatives will be implemented with aims to inform both residents and tourists on Bengal fox conservation. Additionally, legislation efforts will be made to declare Karnataka a "Closed Area" under the Wildlife (Protection) Act, 1972 which will discontinue hunting in the region. Following this, native grasslands will be restored through agency and community replanting and seeding projects.

Natural History

Species Identification

Bengal foxes are one of the worlds least studied and lesser-known threatened species. Much is yet to be learned from the fossil record involving taxonomic relationships. However, the remains of *Prototocyon curvipalatus*, thought to be from the early Pleistocene, were recovered from the Siwalik Hills, India which showed an association of skull and mandible with Bengal foxes (Gompper and Vanak 2006). Bengal foxes are a small canid and can be distinguished from other foxes of the Indian subcontinent (*Vulpes vulpes, V. v. pusilla, V. v. griffithii, V. v. montana*) by several morphological features (Gompper and Vanak 2006). Bengal foxes have a smaller body size compared to red foxes and its subspecies. Its body has silver-grey to yellow-grey pelage which may become more lush during winter months (Jhala and Johnsingh 2004; Gompper and Vanak 2006). This grey body-color transitions to a cream or ivory underside and tan-brown colored legs (Jhala and Johnsingh 2004). Their tail is bushy and up to 2/3 the length of their body with a distinct black tip (Vanak 2005). The skull is characteristically flattened and has a pointed snout region (Hubbarb 2019). Their ears are pointed and dark brown with black margins (Gompper and Vanak 2006). The nose, mouth, and tear markings around the eyes are black (Jhala and Johnsingh 2004). The average weight for males is between 2.7 and 3.6 kg, and for females approximately 1.8 kg. Measurements of the specimens found at the Bombay Natural History Society Museum are as followed; male's head and body length of 500 mm with the tail measuring 289 mm, and female head and body length of 472 mm with a tail length of 289 mm (Jhala and Johnsingh 2004).

Figure 1. Indian fox, easily identified by grey pelage and distinctive, black-tipped tail (Vanak 2005).

Distribution

Bengal foxes inhabit the Indian subcontinent and are the most common fox species in India compared to the red fox and its three subspecies (Gompper and Vanak 2006; Kumara and Singh 2012). Their distribution encompasses the foothills of the Himalayas and Terai of Nepal to areas in peninsular India and from southeastern Pakistan to eastern India including parts of southeastern Bangladesh (Jhala and Johnsingh 2004; Gompper and Vanak 2006). Their northern range is comprised of the Sindh province of Pakistan to northern Bengal in India (Jhala and Johnsingh 2004). The distribution may extend further into Bangladesh with the decline of the Sundarbans mangrove area (Gompper and Vanak 2006). Bengal foxes were found to be absent in forest of the Western and Eastern Ghats, as well as India's coastal region (Kumara and Singh 2012). Populations have not been detected in neighboring Afghanistan or Iran (Gompper and Vanak 2006).

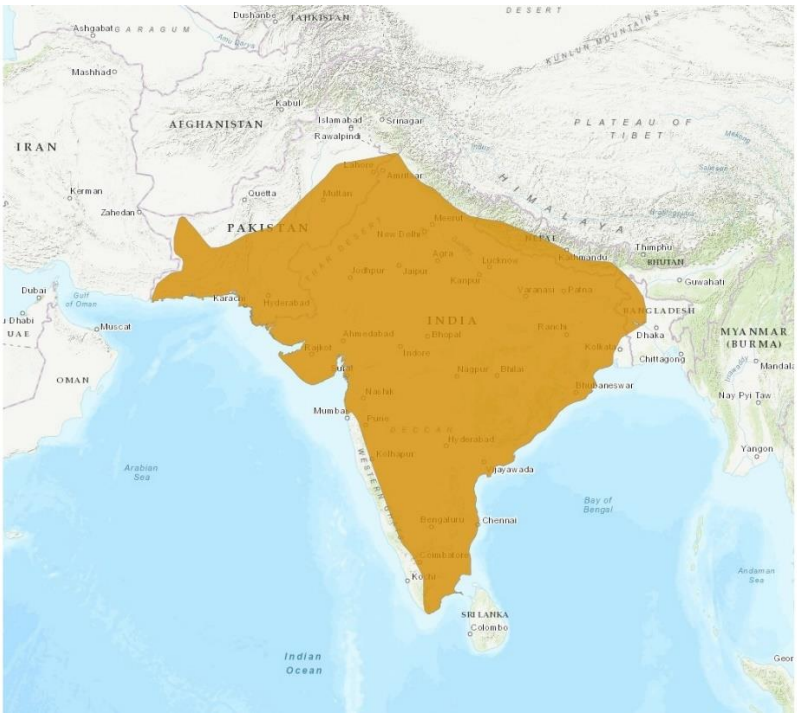

Figure 2: Geographical range of Bengal foxes (IUCN 2008). Bengal foxes have low population densities throughout their range (Vanak 2005).

Figure 3: This management plan only concerns the Bengal fox population within the state of Karnataka. Karnataka has a land area of 191,791 km^2 (Kumara and Singh 2012).

Habitat

Bengal foxes prefer semi-arid thorn, scrub, or dry deciduous forests and short grassland habitats (Jhala and Johnsingh 2004). Bengal fox populations maintain low densities throughout most of their range and reach their highest densities in grassland habitats (Vanak 2005). They are somewhat tolerant of habitat disruption and will inhabit fringe areas along agricultural fields and rural settlements (Gompper and Vanak 2006). Likewise, Bengal foxes will opportunistically den in anthropogenically derived structures such as boulder piles and earthen bunds over naturally occurring sites (Chellum et al. 2013). Areas with thick forest, steep terrain, deserts, and tall grasslands are avoided by foxes due to a lack of available resources and difficulty denning (Jhala and Johnsingh 2004). During the monsoon season, Bengal foxes will rest under shrubs and trees in forested plantations (Gompper and Vanak 2010). Some high-density populations exist in protected areas established for great Indian bustards (*Ardeotis nigriceps*) and Indian blackbuck (*Antelope cervicapra*) as these species utilize similar habitat requirements (Vanak 2005).

Diet

Bengal foxes are opportunistic omnivores, with relatively high variation in diet due to temporal and spatial factors (Jhala and Johnsingh 2004; Home 2005; Gompper and Vanak 2006). Their diet is made up of mostly arthropods, including grasshoppers, crickets, beetles, ants, termites, and spiders (Jhala and Johnsingh 2004). Home (2005) found significant variances in the number of orthopterans, coleopterans, termites, and scorpions consumed by individuals in grassland habitat compared to scrubland habitat. The percent of reptiles and fruits in scats were significantly different between scrubland and grassland habitats, and other food-items varied in both habitats during particular seasons (Home 2005). Rodents constitute a major food source for Bengal foxes, including species like Indian gerbils (*Tatera indica*), field mice (*Mus booduga*), and soft-furred field rats (*Millardia meltada*) (Jhala and Johnsingh 2004). Bengal foxes inhabiting scrubland consume more rodents than those in grassland habitats, likely the result of higher gerbil densities in those areas (Home 2005). It has been reported that pups depend more on rodents as a primary food source compared to adults, as pup scats gathered from Rollapadu Wildlife Sanctuary were mostly composed of rodent fur (Manakadan and Rahmani 2000). Foxes will depredate ground-nesting birds with their eggs, including species such as ashy-crowned finch larks (*Eremopterix grisea*), Indian mynahs (*Acridotheres tristis*), and even great Indian bustards (Jhala and Johnsingh 2004; Manakadan and Rahmani 2000). On occasion, Bengal foxes will consume reptiles including rat snakes (*Ptyas mucuosus*) and various ground lizards (Jhala and Johnsingh 2004). As omnivores, they consume many types of fruit including Indian jujube (*Zizyphus mauritiana),* mango (*Mangifera indica*), and neem (*Azadirachta indica*) amongst others (Jhala and Johnsingh 2004). Large animal carcasses are not a significant food source, making up only 1% of their diet (Bopanna et al. 2012).

Life Cycle/Reproduction

Due to insufficient data concerning Bengal fox population dynamics and reproduction, some data has been interpolated from various populations of red foxes as they are the closest related species and certain subspecies are sympatric (Gompper and Vanak 2006). The age classes identified for Bengal foxes are pup, juvenile, young adult, adult, and old adult (Figure 4). Bengal foxes have an average lifespan of 6-10 years (Jhala and Johnsingh 2004; Meadors 2007). Korytin (2002) noted that the oldest observed red fox in the Ural Mountains (area around Kirovoblast, Sverdlovsk, Kurgan, and Tyumen), Russia was 11 years.

The breeding season is influenced by increased prey abundance during the monsoon season and can be noted by the digging of new dens, excavating of old dens, and calling by males (Manakadan and Rahmani 2000; Jhala and Johnsingh 2004; Gompper and Vanak 2006). At the start of the breeding season, males will usually bark repeatedly just after nightfall and before sunrise, though occasionally they will call through the night (Jhala and Johnsingh 2004). The gestation period usually lasts for 50-53 days, with births occurring between January and May (Manakadan and Rahmani 2000). Red foxes may become reproductively viable as yearlings and may remain so in old age if the population density in their home range is low and resources are abundant (Allen, 1984; Korytin 2002). Helpers have not yet been observed at den sites (Gompper and Vanak 2006). Nursing by more than one female has been observed, but it is uncertain how females were related (Gompper and Vanak 2006). Lactating females require more water than non-lactating females or males, and the availability of water influences den site location for this reason (Home and Jhala 2010). Breeding pairs will remain together for several seasons with pair bonds persisting past reproduction and into the 4–5-month long pup-rearing period (Jhala and Johnsingh 2004; Gompper and Vanak 2006). Litter sizes range between 2-4 pups, with the average litter size being 2.7 in Gujarat, India (Jhala and Johnsingh 2004). Reproduction rates for Bengal foxes fluctuate annually according to prey abundance (Jhala and Johnsingh 2004). Young will disperse at or near the onset of the monsoon season, taking advantage of influxes in prey (Jhala and Johnsingh 2004).

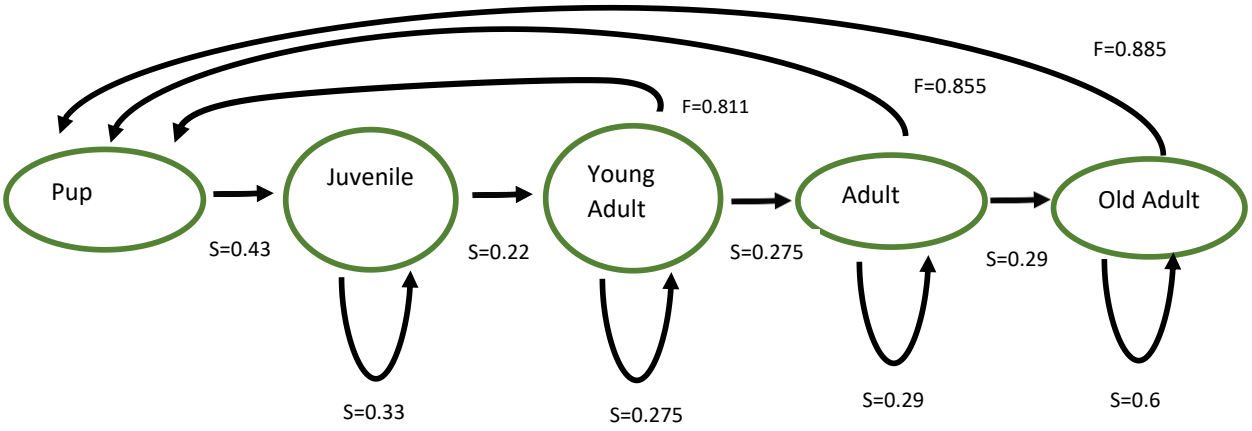

Figure 4: Life cycle, survivorship, and fecundity values of Bengal foxes. Life stages are pups (0-5 months) juveniles (6 months-2 years), young adults (3-4 years), adults (5-6 years), old adults (7-8+ years).

Denning Behavior

Dens of Bengal foxes are utilized only during the pup-rearing season, though they return to the same site annually (Jhala and Johnsingh 2004). There are three general types of dens used by Bengal foxes: 1. small dens with two openings used as brief resting areas in midday, 2. larger dens with multiple openings, used during the reproduction-period, and 3. dens under rocks or rock crevices, also used in the reproduction-period (Gompper and Vanak 2006). Den sites are almost always in open areas where predator detection is highest (Manakadan and Rahmani 2000; Chellum et al. 2013). In a study conducted by Kumara and Singh (2012), all den sites occurred in open and exposed areas devoid of vegetation (the nearest shrub was 50 m from the den site), except for two dens which were underneath vegetation. All dens found by Home and Jhala (2010) occurred within 2 km of a water source. During the lactation period, females require additional water, which is a limited resource in semi-arid grasslands, making den location reliant on water availability (Home and Jhala 2010). On the inside, dens are composed of tunnels, each of which are under a different stage of excavation (Jhala and Johnsingh 2004). The series of tunnels leads to a small chamber about 0.5-1 m in size where the pups are born (Jhala and Johnsingh 2004). Adult foxes remain within 100 m of the den during pup-rearing and exhibit extremely protective behavior for their young (Home and Jhala 2010). Once foxes are denning, they are typically stationary until the pups can walk (Jhala and Johnsingh 2004). During the denning period, both adults will bring food for the young (Jhala and Johnsingh 2004). After the offspring are mobile (usually after 1 month), foxes will switch between any of the dens in the adult's territory in avoidance of predators (Manakadan and Rahmani 2000; Home and Jhala 2010). Kumara and Singh (2012) found that there were more inactive dens in their observed protected area than there were in surrounding (private) land, which they attributed to higher rates of den

switching in the absence of humans. In avoidance of humans, dens are usually established at least 3 km away of any human settlement (Home and Jhala 2010). However, Chellum et al. (2013) found that most dens in their study area were made from anthropogenic structures including earthen bunds, and boulder piles over other local substrates.

Diseases

Diseases such as canine parvovirus (CPV), canine distemper virus (CDV), and canine adenovirus (CAV), have caused population declines in threatened canids throughout Southeast Asia (Adhikari et al. 2020; Belsare et al. 2014). CDV in particular has been responsible for increased mortality of Bengal foxes in India (Belsare et al. 2014). Belsare et al. (2014) reported that there was a minute presence of CDV antibodies in Bengal foxes (12%) as well as high mortality rates among the CDV-positive foxes sampled. CDV, CPV, and CAV likely reached target populations of wild canids from source populations of free-ranging domestic dogs (Belsare et al. 2014). Domestic dogs have become the most abundant canid throughout many regions of India in relation to the increasing human population (Srivathsa et al. 2019). The role of dogs as human and livestock protection enable their free-ranging tendencies, ultimately leading to negative interactions with wildlife (Belsare and Gompper 2015). Belsare et al. (2014) found that more than 72% of adult dogs in villages near the Great Indian Bustard Wildlife Sanctuary tested positive for CDV, CPV, CAV, or their associated antibodies. The Great Indian Bustard Wildlife Sanctuary is one of the few protected, semi-arid grasslands in India with a known population of Bengal foxes (Vanak 2005). Isolated populations of Bengal foxes in protected areas are often devastated by outbreaks of disease. A population of Bengal foxes in Rollapadu Wildlife Sanctuary decreased from 40-50 individuals in 1994 to 10 individuals in 1995 due to an outbreak of what was likely CDV (Manakadan and Rahmani 2000). Management of enzootic diseases spread by free-ranging dog populations is complicated because of their wide distribution, complex role in ecological relationships, and because interactions between hosts and pathogen are not fully understood (Belsare and Gompper 2015). To further complicate management, recovery from CDV, CPV, and CAV is more common in domestic dogs than it is in Bengal foxes. Once dogs recover from these diseases, they are immune to them for life, however herd immunity is never met in these populations as dogs have a high population turnover rate (Belsare et al. 2014). Belsare and Gompper (2015) modeled CDV dynamics of a two-host system, with dogs representing the source population and foxes as the target. The outcome of the model revealed that dog vaccination does not reduce the spread of CDV and that vaccinating Bengal foxes would be the best method of CDV reduction (Belsare and Gompper 2015). There are both positive and negative aspects of solely vaccinating the Bengal fox population. It would be much more cost effective to vaccinate the small population of Bengal foxes as compared to the exponentially growing domestic dog population.

Additionally, without testing each dog, it would be difficult to discern which individuals have contracted and developed natural immunity to CDV, CAV, and CPV (Belsare et al. 2014). A drawback of vaccinating Bengal foxes for CDV, CAV, and CPV is that these vaccinations need to be given via injection, as oral vaccinations have not yet been developed. This would require all Bengal foxes in Karnataka to be live-trapped, anesthetized, and vaccinated on an annual basis due to the continuous threat of CDV spillover events by free-ranging dogs (Belsare and Gompper 2015). Similar vaccination interventions have been performed in south-central Ethiopia in treating Ethiopian wolves (*Canis simensis*) for rabies (Knobel et al. 2008).

Conservation Needs

Ecological

The greatest threat currently facing Bengal foxes in Karnataka is habitat loss (Jhala and Johnsingh 2004). Their optimal habitat consists of semi-arid, short grassland or deciduous, thorny scrublands (Jhala and Johnsingh 2004). Although they have a large range, high population densities are only found in short grassland habitats (Vanak 2005). Short grasslands make up a small proportion of available habitat. There have not been any protected areas created to protect Bengal fox populations. However, they live in high densities on protected areas established for species that utilize similar habitat requirements including the Great Indian Bustard Wildlife Sanctuary and Jayamangali Blackbuck Block (Kumara and Singh 2012). Chellum et al. (2013) reported that majority (23%) of short grassland habitats near and/or within the Great Indian Bustard Sanctuary were on communal or private lands with high risk of human modification. The same is true across much of southern India, where only 2% of Bengal fox habitat is on protected land (Vanak 2005). Bengal foxes in Karnataka require the establishment or enlargement of protected grassland areas that pose no threat from human modification to increase local population densities.

Though Bengal foxes are somewhat tolerant of human habitation, they avoid human-derived food sources and are frequently disturbed by people, grazers, and dogs (Manakadan and Rahmani 2000, Gompper and Vanak 2007). Bengal foxes avoid agricultural areas due to the lack of arthropods caused by continual pesticide application (Chellum et al. 2013). Population growth is largely dependent on maintaining reproductive success on an annual basis. In a protected setting, success during the reproductive period largely depends on resource availability and rainfall as Bengal foxes maximize reproductive output in resource rich years (Home and Jhala 2010). However, on a human modified landscape reproductive success is dependent on the habitat type of the denning area and by minimizing interactions with humans, conspecifics, and predators (Kumara and Singh 2012). Chellum et al. (2013) showed that Bengal foxes select denning sites near semi-arid grasslands at the home-range scale and did not exhibit selective

behavior towards other habitat types. Den sites utilized during pup-rearing usually maintain a distance of at least 3 km from human settlements (Home and Jhala 2010). Denning locations and available protected habitat for Bengal foxes are highly fragmented and becoming increasingly developed. Therefore, the location of newly established or expanded protected areas should be distanced at least 3 km from human populations to reduce stress and increase reproductive success (Home and Jhala 2010).

Economic

Livestock production is of utmost importance to the Indian economy. The production of livestock contributes 4% to the Indian national gross domestic product and provides employment and overall livelihood for 70% of the communities in rural India (Roy and Singh 2013). India has a large livestock sector, with the livestock population totaling around 623 million (Roy and Singh 2013). Due to the high numbers of livestock in these areas, overgrazing has become a major source of habitat destruction in grasslands (Jhala and Johnsingh 2004; Kapuria 2021). The current needs of livestock in India and the adverse effects they have on wildlife species that inhabit grasslands will be intensified as livestock populations are expected to increase at a rate of 0.55% annually (Roy and Singh 2013). Local communities containing predominately pastoralists and farmers should be given revenues from localized protected areas to decrease the number of livestock grazing on Bengal fox habitat while evading poverty (Winkler 2006).

India has been experiencing a period of economic growth (6-9% annually), globalization, urbanization, and increased tourism (DeFries and Karanth 2010). With the doubling of India's middle class, the rate of ecotourism to India's protected areas has increased (DeFries and Karanth 2010). The number of visitors to 10 protected areas throughout India were examined from 2002-2008 and showed that growth rates varied from 7% in Nagarahole to 45% in Periyar (DeFries and Karanth 2010). Demographic statistics of tourists entering protected areas show that 80% of ecotourists in West Bengal were residents of that state, and that only 8% hailed from international origins (Karmakar 2011). Due to the lack of public appreciation and knowledge of Bengal foxes, it is difficult to accurately calculate their monetary value. However, increases in domestic tourism to protected areas generates an opportunity for public support of conservation practices through public education of Bengal foxes and their role in the ecosystem (DeFries and Karanth 2010).

Sociocultural

Grassland and shrublands in India have become highly degraded through anthropogenic impacts such as the spread of invasive plant species and increased land clearance rates and development (Kapuria 2021). Human development of Indian grasslands has largely resulted from urbanization and industrialization

(Vanak 2005; Vanak et al. 2017). Nearly 4000 ha of grassland in Karnataka was diverted for scientific research by organizations including the Indian Institute of Science, Indian Space Research Organization, Bhabha Atomic Research Centre, and Defense Research and Development Organization (Vanak et al. 2017). Land-use alteration of this type is not beneficial for wildlife including Bengal foxes and though it is too late to halt progress on these projects, it is not too late to prevent further development of grasslands. Protected areas are the most crucial component to protecting and conserving natural habitats as well as wildlife (Winkler 2006). If grasslands were incorporated into India's protected area network, they would be free from the threat of human development.

In rural grassland communities, livestock rearing largely supplies employment and income (Roy and Singh 2013). Nomadic pastoralism has remained the predominant grazing technique in semi-arid grasslands of western India, though it has proved unsustainable (Roy and Singh 2013). The low productivity and patchy distribution of the pasture means that pastoralists and their livestock need to travel long distances for seasonal influxes of resources (Vanak et al. 2017). Current management practices outside protected areas cater to this type of livestock grazing even though it contributes to grassland degradation (Kapuria 2021). Efforts have been made to increase pastoralist incomes by providing market access and increasing fodder to ensure higher and consistent production, resulting in less movement across the landscape (Vanak et al. 2017). This initiative is destructive because the reduced mobility of pastoralists results in restricted use of grasslands which in turn causes highly concentrated use and degradation (Vanak et al. 2017). The creation or expansion of protected grassland areas would be the most effective solution to overgrazing practices, although this acts against the economic interests of local livestock owners (Winkler 2006). To mitigate the adverse effects to the local economy, protected area revenues would be distributed to local communities. In doing this, threats of poverty would be alleviated in local communities and incentive for economic improvement through habitat creation/restoration would be exemplified (Winkler 2006).

Canids including Bengal foxes are often hunted to prevent and/or reduce depredation events on livestock. The persecution of foxes for this reason is gratuitous, as Indian wolves (*Canis lupus pallipes*) and golden jackals (*Canis aureus indicus*) are responsible for most depredation events on livestock (Srivathsa et al. 2019). Additionally, many rural and tribal communities hunt Bengal foxes. The nomadic Narikurava people are known to catch foxes with nets or use homemade, fat-covered bombs to kill foxes primarily for their meat, claws, teeth, and skin (Jhala and Johnsingh 2004). There are regional variances in the methods used to hunt Bengal foxes. In the area around Rollapadu Wildlife Sanctuary, locals hunt Bengal foxes using smoke, nets, and dogs at their den sites (Manakadan and Rahmani 2000). The people of Tamil Nadu block the holes of Bengal fox dens with stones to entrap them (Jhala and Johnsingh 2004). Many rural

communities Bengal foxes are hunted to prevent and/or reduce depredation events and are then used in ritualistic ceremonies during religious festivals (Vanak 2005). Bengal foxes are often the target of tribal hunters in rural communities making existing policy preventing Bengal fox hunting futile. Subsidizing poachers would also be futile because poaching events are unobservable and any additional income sources received would complement, rather than substitute, existing activities (Winkler 2006). Even though monitoring poachers on private lands is impossible, protected areas could be more easily monitored to safeguard the Bengal fox population.

Legal/Regulatory

The Indian Wildlife Protection Act (WPA) was implemented in 1972 to ensure protection for wild animals, birds, and plants. Based on this law, species receive varying levels of protection according to their schedule classification (Bist 1999). Amendments made after enactment have added species to the protection list and raised/lowered the schedule listing of others, but no additional protection has been provided for the Bengal fox population (Bist 1999). Bengal foxes belong to Schedule II (part I) which prohibits their harvest but offers no other protection. Additionally, India's protected areas do not target grassland and shrubland habitats preferred by Bengal foxes (Vanak 2005). Protected lands account for only 5% of India's 3.29 million km^2 land area with most of this being heavily forested (Srivathsa et al. 2020). Conserving scrubland habitat in India is difficult because it is considered unproductive 'wasteland' and often converted to agriculture or diverted for commercial use and is rarely managed by the forest department (Vanak et al. 2017; Srivathsa et al. 2019). Scrublands and grasslands need to be included in protected areas to ensure that the species which inhabit them are free from poaching and the pressures of overgrazing by livestock. This could be accomplished through the expansion of existing protected grasslands or the creation of new protected grasslands. An alternative avenue for grassland protection was exemplified by the Rajasthan State Government in the 1980's as they made a gazette notification declaring 14,690 km^2 of semi-arid wildlife habitat as 'Closed Area' with aims to decrease poaching events on vulnerable mammalian species (Bajpai et al. 2018). This benefitted many threatened species in that region including Bengal foxes, great Indian bustards, Indian grey wolves, Indian desert foxes, and blackbucks among others. However, by 2002 the Rajasthan State Government had lost special protection over the closed area, causing populations of threatened species to decline in the region (Bajpai et al. 2018). If the Karnataka State Government could successfully declare potential Bengal fox habitat as closed area, many wildlife species including Bengal foxes would benefit. The current laws and policies protecting Bengal foxes in India are not enough and are attributing to their low population densities. Policy needs to be implemented in India and more specifically Karnataka to conserve the population of Bengal foxes which inhabit the region. This policy must include the expansion or creation of protected

grassland areas, or declaration of potential Bengal fox habitat as closed area to discourage hunting, harassment, and adverse impacts to Bengal foxes and their associated habitat.

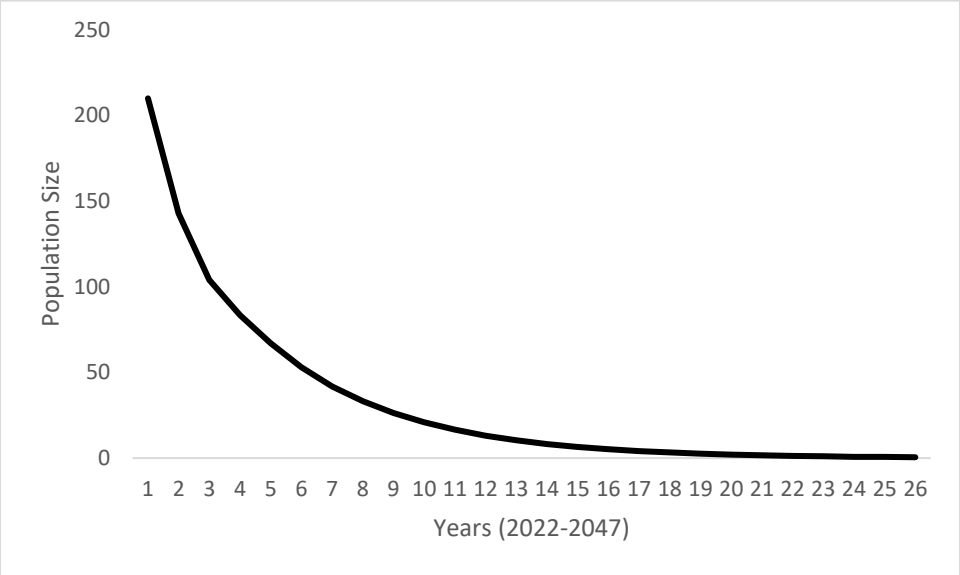

Figure 5: Bengal fox population trend in Karnataka, India. This trend was created assuming a population of 210 individuals and estimates population dynamics if conservation actions are not taken according to the anticipated timeline.

Statement of Need

As described above, there are multiple economic, sociocultural, ecological, and legal concerns which require management of Bengal foxes in Karnataka. Outside of India's protected areas, human activities such as poaching, and habitat destruction have caused lowered population densities of Bengal foxes (Vanak 2005). Poaching and parts trade of Bengal foxes by rural communities and native tribes occurs in many regions regardless of current policies barring such activities (Jhala and Johnsingh 2004; Vanak 2005; Srivathsa et al. 2019). Habitat loss is a multifaceted threat to Bengal fox populations. As pastoralists and farmers increase their livestock holds annually (Roy and Singh 2013), the effects of overgrazing, water scarcity, and general landscape degradation increase (Kapuria 2021). However, cultural heritage, subsistence living, and the historical perception of grasslands as 'wastelands' make it difficult to regulate agricultural practices (Vanak et al. 2017). The effects of increased human development and land clearance in the face of India's current economic growth has also contributed to habitat loss (DeFries and Karanth 2010; Vanak et al. 2017). With the amount of available Bengal fox habitat dwindling, protected areas must be established or expanded to supply a refuge for high population densities to occur. A management plan as such, that considers current threats to Bengal fox populations while balancing the needs of local communities, is necessary for long term success.

Goal

Increase the population of Bengal foxes to carrying capacity (approx. 10000 individuals) in Karnataka for the benefit of their ecosystem and ecotourism industry.

***Objective 1*:** Estimate habitat suitability for 100% of accessible grassland areas in Karnataka in 5 years

Action 1.1: Gain 50% local landowner permission to conduct research on lands which are within Karnataka in a 3-month period.

Protected grasslands areas in India are often highly fragmented, occurring between parcels of private lands (Chellum et al. 2013). Gaining support and permission from local landowners is imperative to this management plan. By gaining local landowner permission through telephone, email, or direct contact, fieldwork can be conducted on private lands, which will give a full evaluation of Bengal fox habitat suitability in Karnataka. Permission will be requested via telephone by one of 12 field crew members hired for this this objective.

Contact rate quantification:

- High Success: 50-100% of landowners contacted
- Moderate Success: 30-49% of landowners contacted
- Low Success: 10-29% of landowners contacted
- Poor Success: 0-9% of landowners contacted

Permission rate quantification:

- High Success: 76-100% permission on public/private lands
- Moderate Success: 51-75% permission on public/private lands
- Low Success: 26-50% permission on public/private lands
- Poor Success: 0-25% permission on public/private lands

Action 1.2: Use stratified random sampling to select the location of 250 vegetation survey sites on public and accessible private lands in 3 months

Karnataka is comprised of 191,791 km^2 (Kumara and Singh 2012). Use of stratified random sampling will reduce the amount of land/time needed for vegetation surveying. Determining cover type in Karnataka will help locate areas of high Bengal fox density. Bengal foxes only occupy short, semi-arid grasslands in high population densities (Vanak 2005). Land cover at each site would be summed into one of 10 categories including: 1. water, 2. evergreen forest, 3. semi-

evergreen forest, 4. mixed forest, 5. deciduous forest, 6. open scrub forest, 7. tropical thorn forest, 8. grasslands, 9. croplands, or 10. desert (Vanak 2005).

Action 1.3: Perform vegetation surveys of 250 sites in a 3-year period

Bengal foxes only occur in high densities in semi-arid, short grasslands and may occur in moderate-low densities in shrublands and fringe agricultural land (Vanak 2005; Chellum et al. 2013). Location of these areas are essential in locating Bengal fox populations. However, overgrazing by livestock occurs throughout semi-arid grasslands in southern India, causing degradation and low productivity which is a main concern for Bengal fox habitat (Vanak 2005; Roy and Singh 2013). Due to the high mobility of nomadic pastoralists in Karnataka, the degree of degradation expressed on the landscape varies annually (Vanak et al. 2017). The annual variability in patchiness of grasslands will require annual surveys to be undertaken for a minimum of three consecutive years.

Den sites are important for successful reproduction as well as monitoring of pup survivorship (Jhala and Johnsingh 2004; Gompper and Vanak 2006). Den sites are almost always made in open areas where predator detection is high (Chellum et al. 2013). To determine the location of possible denning areas, vegetation surveys will be carried out by four crews of three individuals. Each crew will survey a specific region (North, South, East, and West) of Karnataka. Each survey site will need to be marked using GPS for mapping purposes. Based on the preferred habitat and area for den sites (Gompper and Vanak 2006), two types of measurements will be taken; 1. height of grass per 15 m plot, 2. average visual obscurity measured at the center of 15 m plot taken at points North, South, East, and West.

<u>Cover Types of the Study Area:</u>

1. Water, 2. evergreen forest, 3. semi-evergreen forest, 4. mixed forest, 5. deciduous forest, 6. open scrub forest, 7. tropical thorn forest, 8. grasslands, 9. croplands, 10. desert

<u>Grassland habitat suitability:</u>

- Excellent Habitat: grass height <66-75 cm
- Good Habitat: grass height 76-85 cm
- Median Habitat: grass height 86-95 cm
- Poor Habitat: grass height >96 cm
- N/A: No grasses in area, area converted to agriculture, urban, or other undesirable cover type

Den site suitability (Visual Obscurity):

- Excellent Den Site: <25% Visual Obscurity
- Good Den Site: 26-50% Visual Obscurity
- Median Den Site: 51-75% Visual Obscurity
- Poor Den Site: >75% Visual Obscurity

Action 1.4: Develop a land cover map in ArcGIS based on the cover types and preferrable habitat of the 250 survey sites in a 1-year period.

In ArcGIS, a base map of Karnataka, India would be utilized. Layers for cover types would be added based on compiled data gathered in Action 1.3. Each survey site would represent the land cover for a 767 km^2 area on the map. Each survey site would be identified by its cover type. Locating short grassland areas in Karnataka is most crucial because it will aid researchers in finding high population densities of Bengal foxes (Vanak 2005). As short grasslands (<66-75 cm) are the preferred habitat of Bengal foxes, this cover type would be categorized as "Excellent". Additional classifications of grassland areas are "Good" (76-85 cm), "Median" (86-95 cm), and "Poor" (>96 cm) habitat. Based on the high visibility preferred at denning locations (Chellum et al. 2013) plot areas would be categorized as being "Excellent" (<25% Visual Obscurity), "Good" (26-50% Visual Obscurity), "Median" (51-75% Visual Obscurity), or "Poor" (>75% Visual Obscurity) denning areas. The attributes of the survey sites would be implemented into the map following these categories.

No Action: If no action is taken then it would be difficult to comprehend the land cover types or condition of grasses in Karnataka due to rapid land-use alterations and patchiness of overgrazing (Roy and Singh 2013; Kapuria 2021). Without this baseline knowledge it would not be possible to target locations with Bengal fox populations in Karnataka due to their wariness of humans, elusiveness, and low population densities (Vanak 2005; Gompper and Vanak 2010; Chellum et al. 2013).

Final Courses of Action: Action 1.1 needs to be implemented first and will be completed within 3-4 months. Before research is conducted on private lands, permission from landowners needs to be granted. Action 1.2 will follow, establishing random survey sites on private and public lands throughout Karnataka over a span of 2 months. Action 1.3 will be implemented, with fields crews conducting vegetation surveys from May-September for three consecutive years. Action 1.4 will be implemented to gain a map of habitat suitability for Karnataka over the course of a year.

Assessment Protocol 1: Objective will be achieved after a strong estimate of Bengal fox habitat suitability has been produced and displayed in a map. A strong estimate would consider factors such as grass height, visual obscurity, and past or reported sightings of Bengal foxes in/around the survey plots. Bengal foxes are more likely to have higher population densities in short grassland habitats (Vanak 2005) and have dens in grassland areas with high visibility (Chellum et al. 2013). Permission from landowners is required before field surveys can be conducted. At least 50% of landowners need to be contacted, and of those contacted 75-100% of landowners contacted need to grant permission for this objective to be deemed successful. Actions 1.2, 1.3, and 1.4 will be deemed successful if they are completed following the prescribed timeline.

If objective is not met following the estimated timeline, additional time should be allocated to accomplish the objective. It may take more than three years to acquire sufficient data to understand the ecological patterns and regenerative growth of grasses severely impacted by overgrazing. The impacts of economic growth (6-9% annually) and increased livestock herds (0.55% annual growth) on semi-arid grasslands is not fully understood (Roy and Singh 2013; DeFries and Karanth 2010). Furthermore, it may take additional time to compile, input, clean, and map data from field surveys into ArcGIS. Completion of this objective is pertinent to following objectives and must therefore be accomplished before other management actions can be completed.

Objective 2: Perform mark-recapture study of Bengal foxes in Karnataka maintaining confidence intervals with 95% variability around the population over a 3-year period

Action 2.1: Initial capture and marking of the Bengal fox population on accessible private and public lands over a 1-year period

Performing a mark-recapture study will benefit this management plan and future studies of Bengal foxes. Depending on the method of analysis, results of this study could fill knowledge gaps concerning population dynamics including immigration, emigration, mortality, and natality rates. Bengal fox populations are known to fluctuate rapidly due to outbreaks of diseases such as CDV and rabies (Manakadan and Rahmani 2000). Furthermore, the stresses of habitat degradation due to overgrazing, land-use alterations, land clearance, and the spread of invasive species is largely unknown (Roy and Singh 2013; Vanak et al. 2017). Trapping of Bengal foxes will predominately take place in short grassland areas because it is preferred habitat (Vanak 2005). The number of traps in each location will be based on its estimated habitat suitability determined in Objective 1. Higher numbers of traps would be set in “Excellent” habitat and less

in the subsequent categories. Grasslands would be located using the habitat suitability map generated in Action 1.4. Tomahawk traps (Tomahawk Live Trap Co., Tomahawk, WI) and soft leg-hold traps (Oneida Victor, Euclid, OH, USA) baited with fruits and rotten meat would be used to capture Bengal foxes following the procedure used by Maura and Jhala (2010). All captured individuals would be sexed, weighed, aged by incisor wear, and receive a distinct yellow ear tag as to be identified in the field (Baker et al. 2001). After the initial measurements and marking is completed, the individual will be released.

Action 2.2: Capture/recapture of Bengal foxes on accessible private and public lands for an additional year following initial trapping period

Using the same design as the initial trapping phase, another capture/recapture period would be implemented. The number of individuals with yellow ear tags captured would be recorded. Individuals that were not tagged in the original study will be sexed, weighed, and aged by incisor wear (Baker et al. 2001). Individuals that are recaptured will be assessed for health based on weight, pelage, and overall condition. Prior to release, ear tags will be removed to mitigate adverse effects of the individual in the wild.

Action 2.3: Analysis of the mark-recapture study over a 6-month period

According to the elasticity and sensitivity models created for Bengal foxes in Karnataka, increasing survivorship of the pup and juvenile age classes is the most crucial component to increasing the overall population density. To analyze the results of the mark-recapture study, a Cormack-Jolly-Seber (CJS) model will be implemented (Schwartz and Arnason 2013). The CJS model will be used to estimate survival rates using information including sex, weight, age, and environmental conditions noted by field researchers during the trapping phases (Schwartz and Arnason 2013).

No Action: If no action is taken then survivorship of Bengal foxes in Karnataka cannot be determined. Understanding survivorship of the pup and juvenile age classes is important in raising the population of Bengal foxes to carrying capacity (10000 individuals). Additionally, large populations have been known to fluctuate rapidly due to outbreaks of disease (Manakadan and Rahmani 2000). It would be beneficial to know how often these fluctuations occur and if they are detrimental to population growth. Increased agriculture, industrialization, and urbanization in semi-arid grasslands may have devastating impacts on the population but this is currently unknown (Roy and Singh 2013; Vanak et al. 2017). Completion of this study would supply data which could evaluate these potentially negative influences.

Final Courses of Action: Action 2.1 will be implemented for the first year of the study. Action 2.2 will occur following the completion of Action 2.1 during the consecutive year. Action 2.3 will take place following the second year of Bengal fox trapping.

Assessment Protocol 2: Objective will be achieved following the completion of the mark-recapture study and further analysis of the mark-recapture data. The mark-recapture study will be deemed successful once completed and modeled following the anticipated timeline. Validity of common methods used to estimate population abundance of Bengal foxes such as spotlight surveys are questionable as they rely on opportunistic observations and are constrained by vehicle access and will not be considered as an alternative for this objective (Maurya and Jhala 2010). If the objective is not completed following the anticipated timeline, additional time should be allotted to complete the study. The results of this study will report information that is pertinent for this management plan and future Bengal fox studies. It may take more than 6 months to compile data and complete analysis of the mark recapture study. Additionally, subsequent trapping may be necessary following the first two years of the mark-recapture study. Gaining a holistic view of the Bengal fox population throughout the state of Karnataka may require more than two-years of data. If this is true, then an additional 1-2 years of mark-recapture will take place.

Objective 3: Provide public education to 25% of ecotourists visiting localized protected lands and 25% of residents in Karnataka to promote Bengal fox conservation practices over a 4-year period

Action 3.1: Distribute educational brochures targeting ecotourists at localized protected areas over a 3 year-period

Ecotourism is a growing industry in many areas of India including Karnataka (DeFries and Karanth 2010). Majority of ecotourists in India are from urban areas and have higher incomes compared to rural communities (DeFries and Karanth 2010). By distributing educational brochures to ecotourists at protected areas I would be reaching an audience which is from predominately urban areas. Educational brochures will be handed out by researchers, volunteers, and protected area employees at tables positioned strategically around facilities. This would generate support among larger urban populations for Bengal fox conservation in rural areas (DeFries and Karanth 2010).

Action 3.2: Include wildlife conservation into all public-school curriculums in Karnataka coinciding with Action 3.1

Wildlife conservation is a current and significant social issue due to increased environmental concerns (Zhou et al. 2016). This is true in India, though it is difficult to balance human well-being and economic development, while also safeguarding nature (Srivathsa et al. 2020). Government policy in India reflects this, as it promotes industrial and agricultural growth rather than wildlife conservation (Vanak et al. 2017). Wildlife conservation is important for humans because wildlife supplies food, clothing, medical materials, and experimental models (Zhou et al. 2016). 84-100% of impoverished households in rural communities of India gather food, fuelwood, fodder, and fiber items directly from the land (Roy and Singh 2013). Utilizing these resources in daily life shows heavy reliance on natural resources including wildlife. Without a scientific understanding of wildlife conservation, it is difficult for many people to obtain unbiased and detailed information on correct harvesting practices and conservation methods (Zhou et al. 2016). Therefore, to supply detailed, unbiased information on wildlife conservation to a maximum number of people in Karnataka, wildlife conservation should be incorporated into public school curriculums.

Action 3.3: Distribute surveys to public schools, protected area facilities, hotels, lodges, and resorts within a 6-month period.

Surveys regarding Bengal fox conservation will be distributed to areas with high numbers of ecotourists such as protected area facilities, resorts, hotels, and lodges. Surveys will also be administered by teachers in classrooms at public schools. It is crucial that these groups are targeted for public education to maximize potential outreach. Domestic ecotourism is a growing industry in India, appealing most to urban populations (DeFries and Karanth 2010). Outreach to the public is critical to ensure unbiased and correct information regarding Bengal fox conservation is construed. By distributing surveys to both groups and analyzing the results, the effectiveness of public outreach methods can be evaluated.

No Action: If no action is taken then biased and undetailed information concerning wildlife conservation will continue to circulate (Zhou et al. 2016). The number of people exposed to current grassland degradation and poaching events on Bengal foxes will remain constant with little potential for growth (DeFries and Karanth 2010). This would negatively impact the Bengal fox population of Karnataka due to a lack of public appreciation and knowledge of their population. Therefore, the ignorance exemplified by tourists and residents concerning their negative impacts on Bengal foxes, as well as their conservation practices will continue.

Final Course of Action: Actions 3.1 and 3.2 will occur simultaneously over a 3-year period. Both actions are necessary to increase recognition of threats facing Bengal foxes including grassland degradation and poaching. Action 3.3 will be undertaken in the 6 months following public education methods. With increased awareness, the prevalence of poaching, overgrazing, free-ranging dogs, and human development on Bengal fox habitat will decrease.

Assessment Protocol 3: Objective is achieved if 25% of tourists and 25% of residents that complete survey can answer the questions with 60% accuracy or higher in the fourth year of this objective. Surveys will be administered to students in classrooms, and ecotourists in and around local hotels, lodges, protected areas, or local attractions during each year of the objective. If objective is not achieved, additional educational initiatives will be implemented following end of this management plan. If public awareness about the threats facing Bengal foxes does not increase, then poaching, and adverse agricultural and development effects will continue (Vanak 2005; Vanak et al. 2017).

Objective 4: Increase survivorship of the pup and juvenile age classes by 20% in a 15 year-period

Action 4.1: Make legislation to have Karnataka declared "Closed Area" over a 3-year period.

"Closed Areas" in India do not allow hunting of any game without a special permit as per the Indian Wildlife (Protection) Act, 1972. Only the state government can instate a "Closed Area" which last for the period announced in the notification, as determined by government officials. This was accomplished in Rajasthan resulting in increased biodiversity for the duration of the notification (Bajpai et al. 2018). Evidence regarding habitat degradation and poaching of Bengal foxes will need to be presented to the Karnataka State Government for review before a declaration can be made.

Action 4.2: Incentivize local livestock owners using revenue from protected areas to discontinue overgrazing on grasslands within a 2-year period.

Livestock rearing is a primary source of income for rural communities in India (Roy and Singh 2013). India contains approximately 500 million head of livestock, in which approximately 50% of resources are taken directly from grasslands (Kapuria 2021). Without income brought in from livestock rearing, these communities would not be able exist. By offering continual income from revenues of localized protected areas, livestock owners would be financially stable enough to stop current overgrazing practices (Winkler 2006; Roy and Singh 2013). Rather than livestock owners solely pasturing their animals, they could supplement with dry feed as well.

Action 4.3: Offer revenue incentives to local landowners to allow grassland restoration practices on their land coinciding with Action 4.2.

The development of grasslands and shrublands for agriculture and industry has drastically reduced Bengal fox habitat (Jhala and Johnsingh 2004). Herbicide application in agricultural areas does not promote the health of native insect populations which are a primary food source for Bengal foxes (Home 2005; Chellum et al. 2013). To mitigate this, preexisting and existing grasslands on public lands will need to be restored, involving the seeding and planting of native plant species. By allowing these modifications to be done to their land, landowners would receive revenue incentives from local protected areas (in some cases, in addition to those received in Action 4.2) for allowing restoration practices on their land. By allocating protected area revenues to local landowners, it would incentivize development of protected wildlife habitat while providing a stable source of income for residents (Winkler 2006).

Action 4.4: Plant native shrubs and grasses in areas impacted by overgrazing and land clearance within 10 years

Bengal foxes are opportunistic omnivores, consuming various rodents, birds, insects, and plants (Gompper and Vanak 2006). By broadcast seeding and planting native grasses and vegetation, the population density of rodents and birds would be expected to increase. Bengal foxes are seasonally reliant on fruits such as mangos (*Mangifera indica*), neem (*Azadirachta indica*), jambu (*Syzygium cumini*), and banyan (*Ficus benghalensis*) (Home 2005; Jhala and Johnsingh 2004). Therefore, it would be beneficial to plant native fruit trees in designated areas. Coinciding with the goals of "Objective 3", to increase public education outreach and overall interest in Bengal fox conservation, I would plan and implement community and public-school tree planting and seeding initiatives in localized areas.

No Action: If no action is taken then Bengal foxes would become extirpated from Karnataka within 15 years. Impacts of poaching and habitat degradation due to lack of public knowledge will negatively impact the population (Vanak 2005). The elasticity and sensitivity matrices produced for this management plan show that the pup and juvenile age classes are the most crucial to increasing the population. If their survivorship does not increase by 20% within 15 years, then the population will continue to decrease at an exponential rate.

Final Course of Action: Action 4.1 will be implemented first, requiring 1-3 years to compile data and present to the Karnataka State Government. Karnataka will need to be declared a "Closed Area" to see decreases in poaching events (Bajpai et al. 2018). Actions 4.2 and 4.3 will

occur simultaneously over a course of 2 years. It would be advantageous to accomplish these actions simultaneously as there would be overlap between individuals eligible to receive revenue incentives. Action 4.4 will be the final action implemented, occurring over a 5–10-year period. This objective will require permission granted from landowners before planting/seeding can begin.

Assessment Protocol 4: Objective will be achieved when pup and juvenile Bengal foxes see a 20% increase in survivorship. This will be determined through direct observations of pups at den sites and solitary juveniles. If information regarding survivorship is not sufficient, another mark-recapture study will be completed over an additional 3–5-year period.

If the objective is not met within 15 years, then managers can determine if more time or adjustment is needed in their actions. It will likely take more than 15 years to gain full support from the public with restoration and sustainable grazing practices as agriculture is a primary livelihood and tradition to these communities (Roy and Singh 2013). Likewise, it may take additional time to accomplish replanting initiatives if public support is not gained and communities cannot be utilized for the replanting process. Public hearings will be held where input from locals will be considered for managers to alter their actions.

Conclusion

This Bengal fox management plan for the state of Karnataka, India has potential to raise the current population to carrying capacity (~10,000 individuals). The degradation of grasslands, numerous poaching events, and presence of free-ranging domestic dogs have caused Bengal foxes to remain below this threshold. Karnataka needs to be declared a closed area, and localized communities need to be educated on the harmful impacts that their traditional practices have on the environment. Protected grassland areas may need to be established or enlarged in future conservation efforts depending on the effectiveness and subsequent success of the closed area following termination of the notification. Additional protected lands will resist further human development of grasslands in Karnataka if this issue escalates. Regardless, traditional agricultural practices can continue when they are maintained at more sustainable levels. Disease outbreaks from free-ranging dogs, as well as poaching, and parts trading are continual threats to Bengal fox populations even with the establishment of a closed area. As these are integral parts of rural and tribal culture, additional public education strategies may be necessary for multiple years including workshops, forums, and seminars in highly impacted localities. By combining current knowledge with statistical and mathematical models, a valuable set of actions and population data has been created. Though additional population studies may be required to obtain data sets which exemplify the full scope

of Bengal fox population dynamics, this management plan supplies researchers and land managers with current population data. By implementing the final courses of action, land managers in Karnataka could accomplish the management goal of having the Bengal fox population reach carrying capacity in Karnataka, India.

Acknowledgements

Thank you to my professors for assisting me while writing this management plan and for knowledge required to complete my degree, and to my family for continual support through my college career and for their unwavering optimism in accomplishing my future goals.

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Appendix A

25 Year Management Plan for Bengal Foxes (*Vulpes bengalensis*) in Karnataka, India

Survey Questions 2022

1. Do you believe that Bengal foxes play an important role in their environment?
    a. Yes
    b. No
    c. Unsure
    d. Other, explain:
2. Do you believe that grasslands are important ecosystems?
    a. Yes
    b. No
    c. Other, explain:
3. Do you believe that there has been more people (i.e., tourists, residents) in your area than there was in previous years?
    a. Yes, there's more people in my area compared to past years
    b. No, there is less people in my area compared to past years
    c. Unsure, I do not notice much/any change
4. Do you think people have a negative or a positive impact on wildlife?
    a. Positive, explain:
    b. Negative, explain:
    c. Unsure
5. Have you had any conflicts with wildlife recently or in the past few years?
    a. Yes, explain:
    b. No
    c. Other, explain:
6. How often do you visit protected lands (including national parks, national forests, protected areas, and wildlife sanctuaries)?
    a. Often (10+ times per month)
    b. Occasionally (3-9 times per month)
    c. Rarely (0-2 times per month)
    d. Never
7. Do you enjoy wildlife viewing and/or birding?
    a. Yes
    b. No
8. Where would you most likely spot Bengal foxes?
    a. Farmland
    b. Woodland
    c. City street
    d. Grassland
    e. Mountain
    f. Desert

   g. Other
9. What type of food(s) do Bengal foxes eat?
   a. Insects
   b. Rodents/Small mammals
   c. Fruit
   d. Reptiles/eggs
   e. Birds/eggs
   f. All the above
10. Do you believe that poaching can lead to extirpation and/or extinction?
   a. Yes
   b. No
   c. Maybe
11. What local animals do you think are targeted by poachers?

12. Would you be willing to participate in community projects to replant local grasslands with native species?
   a. Yes
   b. No
   c. Maybe
13. Are you a male or female (choose one)?
   a. Male
   b. Female
14. What age group do you belong to?
   a. Under 18
   b. 19-30
   c. 31-40
   d. 41-50
   e. 51-60
   f. 61-70
   g. Over 71
15. What is your occupation or if you are a student, what school do you attend?

Appendix B

Timeline for Management Objectives and Actions **Goal:** Increase the population of Bengal foxes to carrying capacity (approx. 10000 individuals) in Karnataka for the benefit of their ecosystem and ecotourism industry.	
Objective 1 (start)	Jan. 2022
Action 1.1 (end)	Mar. 2022
Action 1.2 (end)	Jun. 2022
Action 1.3 (end)	Jun. 2025
Action 1.4 (end)	Jun. 2026
Objective 1 (end)	Jan. 2027
Objective 2 (start)	Jan. 2027
Action 2.1 (end)	Jan. 2028
Action 2.2 (end)	Jan. 2029
Action 2.3 (end)	Jun. 2029

Objective 2 (end)	Jan. 2030
Objective 3 (start)	Jan. 2030
Action 3.1 (end)	Jan. 2033
Action 3.2 (end)	Jan. 2033
Action 3.3 (end)	Jun. 2033
Objective 3 (end)	Jan. 2034
Objective 4 (start)	Jan. 2034
Action 4.1 (end)	Jan. 2037
Action 4.2 (end)	Jan. 2039
Action 4.3 (end)	Jan. 2039
Action 4.4 (end)	Jan. 2049
Objective 4 (end)	Jan. 2049