Fishing Cat Ecology: Food Habits, Home Ranges, Habitat Use and Mortality in a Human-Dominated Landscape around Khao Sam Roi Yot Area, Peninsular Thailand

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Keywords: fishing cat, diet, home range, habitat use, mortality, Thailand

Abstract

Despite their global status as an endangered species, many aspects of fishing cat (*Prionailurus viverrinus*) ecology have not been studied in detail in the wild. The objectives of this study were to understand food habits, habitat use, home range patterns, and causes of mortality in a predominantly agricultural landscape in the area in and around Khao Sam Roi Yot National Park, Prachuap Khiri Khan Province, peninsular Thailand.

Few studies have been conducted on the food habits of wild fishing cats and none has been conducted in Southeast Asia. I identified prey remains in fishing cat scats to estimate composition and relative occurrence of major prey groups in the feces of 194 fishing cat scats collected over an approximately 35 km^2 area. The proportion of prey remains found in scats was 42% fish, 24% mammals, 24%, birds, 5% reptiles, and 2% crustaceans. There was a significant difference in seasonal prey composition ($p = 0.001$). During the dry season, 47% of prey remains found was fish, 11 % mammal, 29% bird, 11% reptile, and 3% crustacean. In the wet season, proportions were 36% fish, 39% mammal, 20% bird, 2% reptile, and 1% crustacean. In this study, fishing cat diet varied more than previously reported, both in terms of the diversity of prey and in the proportions of major groups recorded between seasons.

To study the home range, habitat use, and mortality of fishing cats, I captured seventeen cats (seven females and 10 males) using box traps and fitted 16 with VHF radio collars. Data from these animals (>1000 locations) were used to estimate home range size and habitat selection. Home range size was estimated using 100% Minimum Convex Polygon (MCP) and the 95% Fixed Kernel (FK) methods. Fishing cats essentially maintained their core area for the duration of the study despite seasonal changes in diet. For the 100% MCP, the area of the male annual home

range, F5 was 13.5 km^2 and M8 was 4 km^2 and the mean for female annual home ranges (n=4) was 4.0 km^2. Whereas, the 95% estimates for the male annual home range was 8.8 km^2, and the mean annual home range for females was 3.9 km^2.

Seasonal home range was estimated for one male. His wet season 100% MCP was 10.8 km^2, and his 95% fixed kernel was 12.6 km^2. In the dry season his 100% MCP home range was 5.7 km^2 and the 95% fixed kernel home range was 8.9 km^2. For females (n=4), mean wet season 100% MCP home range was 3.2 km^2 and the mean 95% fixed kernel was 3.1 km^2. The dry season mean 100% MCP was 3.0 km^2 and the mean 95% fixed kernel was 3.2 km^2. There is evidence of overall home range overlap between females but their 50% area had no overlap.

Fishing cats used aquaculture areas and rice fields more frequently, than mangrove restoration areas, and coconut plantations, and human settlement and limestone hills were avoided. One animal used primarily mangrove vegetation (97% of all locations). Coconut plantation was a relatively rare vegetation type within the study area, but it was the most used habitat for one animal in the dry season.

Of 16 cats originally collared, five died from confirmed poaching or retribution killing (31.3%), dead from unknown causes (n=6, 37.5%), unknown fate (n=3, 18.8%), and collar malfunction (n=2, 12.5%). Considering that fishing cats have been known to live to 10 years of age, the sample in this study sustained a relatively high mortality rate. Because poaching and retaliatory killing was the main cause of death, the most effective conservation effort for this species in coastal Thailand should focus on decreasing human-fishing cat conflict and poaching.

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Chapter 1: Food Habits of the Fishing Cat (*Prionailurus viverrinus*) in a Human Dominated Landscape in Coastal Thailand

Introduction

Fishing cats (*Prionailurus viverrinus*) are small wild cats with a discontinuous distribution in mangroves, wetlands, rivers, and swamps in parts of South and Southeast Asia (Nowell and Jackson 1996, IUCN 2010). The species was classified as globally endangered in 2008, based on steep population declines (especially in Southeast Asia) over the past several decades (IUCN 2008). Fishing cats are good swimmers with semi-webbed paws and a relatively short but muscular tail that can be used as a rudder in the water (Roberts 1977). Few studies have been conducted on the diet composition of wild fishing cats, and none has been published based on populations in Southeast Asia. One in-depth study (Haque and Vijayan 1993) was carried out in India and a number of other authors cite ad-hoc observations of diet habits (Jerdon 1874, Prater 1965, Roberts 1977, Sunquist and Sunquist 2002). These studies support a general pattern of fish as the primary food source supplemented by domestic chickens, birds, rodents, snakes, frogs, crabs, mollusks, and insects (Haque and Vijayan 1993, Sunquist and Sunquist 2002, Cutter and Cutter 2009). Fishing cats are known to pursue animals twice their body size (Branford 1988) and there are reports of fishing cats consuming chital (*Axis axis*) fawns (Sunquist and Sunquist 2002, Jerdon 1874), dogs, young domestic calves, and even unattended human infants (Sterndale 1884). Scavenging behavior has also been documented in fishing cats; Haque (1988) observed a fishing cat feeding on a cow's carcass in Keoladeo National Park, India. Vegetable matter such as grass is also commonly found in scats (Haque and Vijayan 1993).

Fishing cat hunting behavior is distinctive in several ways. Bennett (1833) documented a fishing cat wading through shallow water and diving into water in pursuit of prey. Roberts (1977) observed a fishing cat swim up to ducks and Eurasian coots (*Fulica atra*) and, while fully submerged in the water, take the birds from below. Multiple video records of captive fishing cats show the animals readily submerging their head while in pursuit of underwater prey. Fishing cats also use rocks as platforms for scooping prey out of the water (Bennett 1833). Clearly, this species is a very aquatic animal, yet it is also known to forage in non-aquatic habitats.

I analyzed the remains of prey items in scats to document the diet composition of fishing cats in and around Khao Sam Roi Yot National Park in Prachuab Khiri Khan, Thailand. This information contributes to understanding the natural history and feeding ecology of fishing cats and may assist managers and other stakeholders in making better land management and other decisions that affect fishing cats in this and other areas. A better knowledge of fishing cat diet may be valuable for conservation and recovery programs that are necessary to address the species' declining numbers.

Study Area

This study was carried out between January 2009 and November 2011 in a 35 km^2 area near the southern tip of Khao Sam Roi Yot, Thailand's first Marine National Park (DNP 2013) (Figure 1-1). During the study, the area was composed of the following approximate land uses: restored mangrove (21%), agriculture (23%), aquacultural ponds (31%), coconut plantation (9.0%), and human settlement (2.0%). These diverse categories are constantly changing as terrestrial agriculture is shifted to shrimp farms and then are subsequently abandoned. Portions of the national park are part of Thailand's largest freshwater marsh (~70 km^2 total with about half of that within the Park), known to the locals as "Tung Sam Roi Yot" and designated a Ramsar site of international significance in 2008 (IUCN). The area inside the park boundary is composed of sand beaches, limestone mountain karst formations, and secondary mangrove forests. Shrimp propagation ponds and rice paddies are tightly packed against the park's highly interdigitated boundary. The vegetation of the area on the coast consists of scrubby mixed deciduous forest. Seasonal ponds with thick reeds and other similar patches are scattered throughout the study area.

Other fauna in the study area, found in the mangrove and mountainous areas inside the Park, include serow (*Capricornis sumatraensis*), spectacled langur (*Trachypithecus obscurus*), and crab-eating macaque (*Macaca fascicularis*). In agricultural areas, mongooses (*Herpestes javanicus*), and rodents (Muridae) are found on low land in agricultural areas and secondary mangrove sites. The reptile fauna includes pythons (*Pythong reticulatus*), king cobras (*Ophiophagus hannah*), other cobra species, rat snakes (Colubridae), and monitor lizards (*Varanus salvator*). Common birds species (among the total 237 species recorded for the area) (DNP 2013) include the great egret (*Ardea alba*), lesser egret (*Egretta garzetta*), grey heron (*Ardea cinerea*), little cormorant (*Phalacrocorax niger*), and many other wading birds.

The dry season in this area extends from December through June; planned burning often occurs during this time and is initiated by local people to clear fields and to generate new grass for cattle grazing. Many fields are also cleared to prepare for aquaculture (e.g. construction of fish and shrimp ponds). The wet season starts around July and runs through November; heavy rain occurs between August and November. During this season, fish are plentiful in the fields as new fresh water runs from the mountains along the western borders to fill empty ponds. Many rice farmers start cultivating between June and December.

Methods

I assembled a sample of 194 scats as the basis for an analysis of diet. I used several approaches to confirm that scats were indeed from fishing cats. In the field, I used physical characteristics for a preliminary identification. I then compared physical characteristics of hairs in scats with a reference collection of hairs known to be from fishing cats and DNA characteristics with reference fishing cat DNA. Details of each of these procedures are described below.

Scat Surveys

To locate scats, walking and boat surveys were conducted along dikes in and around rice fields and shrimp and fish ponds and along dirt roads and paths where there was evidence of fishing cat movement such as tracks or reports from local residents.

Preparation of Samples

When a scat was located, it was collected wearing rubber gloves and placed into a paper bag. All scats were washed with water over a fine wire sieve using normal tap water to separate contents and remove fine particulate matter. Remaining material for analysis was then placed in netted sacks to dry prior to examination of contents under a dissecting microscope.

Reference Materials

To facilitate robust identification of animal remains in scats, I compiled a reference collection of potential fishing cat prey from captive animals and carcasses found in the study area. Because fishing cats ingest their own hair during grooming, I collected samples of fishing cat hairs from several areas on the body of fishing cats captured as part of a parallel telemetry study of fishing cat home range, habitat use and mortality (Chapter 2). These hair samples were later used to compare with hair found in scats to verify that the scats were produced by fishing cats. Reference collection material was labeled and stored in plastic bags or sealed containers until needed. Hair samples were also collected from 17 fishing cats captured as part of a simultaneous telemetry study of fishing cat movements and habitat use (Chapter 2), and additional hair samples were acquired from a fishing cat carcass recovered in the study area. These hairs were used to compare with hairs found in collected scats.

Identification of prey remains in scat

I assumed the hair was ingested by fishing cats during grooming. Because no predators of fishing cats occurred on the study landscape, I concluded that any scats with fishing cat hair were produced by fishing cats. I further tested fishing cat hair identification by comparing hair collected from a captured fishing cat to hair found in 20 randomly selected scats. Hairs with the same pattern as those collected from a captured fishing cat were found among remains of prey species (e.g. small mammal hair and bones; bird feathers) in all 20 samples I tested. I used several criteria to conclude that a given scat was produced by a fishing cat. Candidate scats were those associated with fishing cat tracks, those found at the site and time period of camera trap locations documenting fishing cats, those clearly produced by trapped individuals, and those found at sites known, from radio telemetry, to be used by fishing cats. Tracks associated with scats were considered those of fishing cats if track shape and sizes were consistent with the ranges of a sample set collected from captive fishing cats (e.g. pad width size 2.3-3.5 cm.). The maximum width of all scats encountered was also recorded.

To confirm that all scats were from fishing cats and not confused with domestic dog, scats > 2.5 cm were not used for this study. Given that the full faunal composition of the study area is poorly documented and compiling a reference collection (e.g. of species-specific hair, feathers, scales) would have been prohibitively time consuming, I categorized prey remains in scats (e.g. bone, feather, hair, and other materials) into six broad taxonomic categories: mammals, fish, birds, reptiles, crabs, other invertebrates.

I also conducted DNA analysis for species identification. This was carried out at the School of Veterinary Medicine, Kasetsart University, Bangkok. To test my hypothesis that scats collected were from fishing cats, four semi-fresh scats collected in the field (all consistent with the physical characteristics of other scats collected) were genetically analyzed to determine the species of origin. The QIAGEN stool amplification kit (http://www.qiagen.com/us/products/catalog/sample-technologies/dna-sample-technologies/genomic-dna/qiaamp-dna-stool-mini-kit/#productdetails) was used for DNA extraction and QIAGEN Multiplex PCR kit (www.qiagen.com/products/pcr/multiplexpcrsystem/multiplexpcr.aspx) was used for DNA PCR amplification. A fragment analysis genotyping method was used to obtain allele sizes of 14 microsatellite markers. Each sample was genotyped three times to obtain accuracy of allele size and reduce error during amplification due to allelic dropout and false allele amplification.

Diet Composition Analysis

I carefully dissected and examined scats and categorized discernable remains into six general categories: fish, mammal, domestic chicken, other birds, reptiles, and crustaceans (I did not include grass in this analysis). To calculate the relative occurrence of each of these categories, I divided the number of scats having each category by the total number of scats (Emmons 1988, Rabinowitz 1989, Grassman 2005, Pia 2003,).

To assess whether there were seasonal differences (Trites and Ruth Joy 2005) in fishing cat diet, I used a Chi-square test on raw occurrence data.

Results

I collected 194 fishing cat scats within the study area between January 2009 and July 2011. Also during this time I collected hair samples from 19 different individual fishing cats (17 that were captured in the course of a related radio telemetry study and two that had been captured in the study landscape and kept in enclosures by local residents).

Fishing Cat Hair Reference Collection, Hair Characteristics, and Sample Identification

Based on the hair reference collection I compiled from confirmed fishing cats, and comparison with samples from all other large carnivore species known from the landscape (both wild and domestic) I noted several hair characteristics unique to fishing cats. Specifically, fishing cat hair (consistent among hairs from various parts of the body) is pale grey at the base, dark or light dark in the middle section, then light grey transitioning into a dark tip (Figures 2a and 2b).

Diet Composition

Scats were found in greater density along dikes, and or edges of fish and shrimp ponds or along rice paddies where water pools with stranded fish were found. Overall proportions of major prey groups were 42% fish, 27% mammal, 24% bird, 5% reptile, 2% crustacean, and 0.5% domestic chicken (table 1-1).

Seasonality

During the dry season (December-June), fish and birds remains represented a relatively higher proportion of the diet (47% and 29%, respectively) than during the wet season (39% and 20%, respectively). In contrast, mammals were only 11% of the diet in the dry season but increased to 39% in the wet season. Reptiles and crustaceans represented an insignificantly different (small) proportion of the diet during both the dry (11% and 3%) and wet seasons (2% and 1%) (χ^2 p-value= 0.001, d.f.2).

Most feathers found in scats were from the Great Egret (*Ardea alba)* and Cattle Egret (*Bubulcus ibis*). The mammals were primarily rats (*Bandicota bengalensis* and *Rattus argentiventer*) which were very common in the study area. Evidence of reptiles was found in only a few cases and could only be identified as an unknown species of snake. Finally, fishing cats likely fed on several species of crabs but identity to species was not possible. Only one scat of 194 collected was found to contain domestic chicken remains.

Hunting and Other Diet-related Behavior Observations.

I frequently encountered multiple scats together in latrines (Figure 1-3). Latrines were almost always located on bare ground that was higher than the surrounding area such as on top of prominent dikes or inside abandoned huts. This observation indicates that scats may have been selectively placed and therefore not always associated with habitat.

Discussion

Fishing cats were opportunistic predators and scavengers in my study area. Consistent with previous research, my results suggest a large portion of fishing cat diet consists of fish (e.g. Haque and Vijayan 1993, Adhya et al. 2011, Sunquist and Sunquist 2002). However, mammals and birds were other important prey items in fishing cat diet in coastal Thailand. Other prey categories included reptiles and crabs which formed 5.5% of fishing cat diet further indicating the diversity of prey items that are often consumed.

I also found seasonal differences in the diet. Overall, fish ranked highest in the fishing cat's diet, regardless of the time of year. However, there was a significant difference in composition of main prey between seasons in that bird remains were found second in frequency in the dry season and mammal remains were more common in the wet season. This observation can probably be explained as follows. During the dry season, most habitats in the rice fields include abandoned shrimp ponds and active ponds that are being drained for shrimp harvesting. These conditions cause some fish to congregate in small, shallow pools where they are easier for the fishing cats to capture. Fishing cat tracks were found around these drying pools during the dry season indicating they were feeding there.

In contrast to mammals, birds were found more frequently in fishing cat scats during the dry season. During the beginning of the dry season (e.g. December), the peak season for migratory bird activity in the area occurs and birds may be easier to capture when they are more abundant. Most of the feathers found in scats were from egrets and herons that roost in the study area at night. Typically mammal prey (e.g. rats) were more dispersed during the dry season. From my study on home range (Chapter 2), fishing cats ranged more widely during the dry season which also may help explain why the diet was more diverse during the dry months versus the wet season.

The majority of local residents share a perception that fishing cats are a main source of predation upon domestic chickens. However, only a very small proportion of the diet of fishing cats in the study area comprised chicken (0.5%); I only found one scat containing remains from a domestic chicken. Additionally, in several cases of reported fishing cat predation upon chickens, I placed camera traps around the site of the predation to try to identify the responsible animal. In only one of five of these cases were fishing cats subsequently photographed in the area. Both of these findings support the conclusion that local perceptions of the threat that fishing cats pose to chickens may be exaggerated.

This study is the first to document a significant seasonal variation in fishing cat diet composition. Furthermore, the diversity of prey groups is greater in the study landscape than that generally described in the literature which reports fish represent a very high proportion of the fishing cat's diet (Haque and Vijayan 1993, Jerdon 1874, Prater 1965, Roberts 1977, Sunquist and Sunquist 2002). By using these insights to inform management decisions and share information with local villagers, it may be possible to adjust the perceptions and attitudes of some local residents to promote conservation of this endangered and unique species of cat in coastal Thailand and in other landscapes with similar ecological conditions.

Chapter 1 Tables and Figures

Table 1-1. Annual and seasonal frequency and percentage of prey occurrence in scats of fishing cats in the study area (N=194).

Category	Frequency of Occurrence			Percent Occurrence		
	All year	Dry	Wet	All year	Dry	Wet
Fish	77.5	34.5	43	42.0%	45.1%	37.7%
Mammal	51	7.5	43.5	27.6%	9.8%	38.2%
Wild birds	44	20	23	23.8%	10.8%	12.5%
Domestic chicken	1		1	0.5%	0.0%	0.5%
Reptile	8.5	6	2.5	4.6%	7.8%	2.2%
Crustacean	2.5	1.5	1	1.4%	2.0%	0.9%
Totals	184.5	76.5	114	100	100	100

Figure 1-1. Map of the study area. The area (marked in red) is approximately 35 km^2 in size and covers both sections of Khao Sam Roi Yot National Park and adjacent agricultural areas.

2a 2b

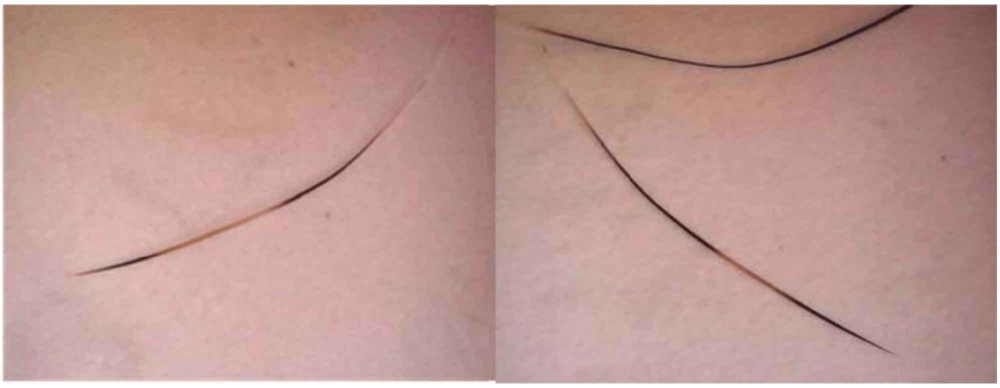

Figure1-2. Comparison of hair collected from a captive fishing cat (2a) versus hair found in scat samples in the study area (2b).

Figure 1-3. Fishing cat “latrine”, which is an area where feces have been densely deposited for months or even years.

Chapter 2: Home Range, Habitat Use, and Mortality of Fishing Cats (Prionailurus viverrinus) in a Human Dominated Landscape in Coastal Thailand

Introduction

Fishing cats (*Praionailurus viverrinus)* are small, solitary, and nocturnal wild cats with a discontinuous distribution in parts of South and Southeast Asia (Nowell and Jackson 1996, IUCN 2010). Fishing cats are good swimmers with semi-webbed paws and a relatively short but muscular tail that can be used as a rudder in the water (Roberts 1977).

Historically, fishing cats occurred throughout the coastal mangroves, wetlands, rivers, and swamps of South Asia (in the Indus Valley, Nepal, India, Sri Lanka and Bangladesh) and Southeast Asia (from Vietnam through Cambodia, Thailand and Java in Southeast Asia). However, most of this habitat has been converted to agriculture and aquaculture, specifically rice and fish farms and the once expansive and more continuous range of the species in Southeast Asia has been reduced to small, isolated, populations (IUCN 2010). Increasingly, observations of fishing cats are reported around human-dominated areas, including recently settled locations where much of the cat's prime habitat has been destroyed (Kolipaka 2006). Habitat loss, together with poaching and retribution killing in response to poultry predation, is thought to have caused a decline of at least 50% in the global fishing cat population over the past 18 years (IUCN 2010, Sanderson pers. comm. 2012). With a global population estimated to be < 20,000 and continuing steep population declines (especially in Southeast Asia) over the past several decades, fishing cats were classified as globally endangered in 2008 (IUCN 2008).

Few studies have been conducted on the ecology of fishing cats and none has documented their detailed movement patterns in the wild. No detailed ecological research has been conducted on the fishing cat in Thailand even though the species is listed as endangered on the IUCN Red List (2011) and is a protected species under the Thailand's Wildlife Protection Law.

Knowledge of species habitat associations is an important component of understanding resource utilization (Gittleman and Harvey 1982). In turn, this information is critical for conservation planning and managing human-wildlife interactions (Gehrt 2009). Additionally, movement of a species are an important aspect of its behavior and ecology (Bekoff and Mech 1984).

In this study, I used standard radio-telemetry methods to document the habitat associations and home range patterns and social relationships of fishing cats in the Khao Sam Roi Yot landscape in Prachuab Khiri Khan Province, Thailand. In the course of the study, I was also able to collect detailed information on the fates of many cats, thus providing insights into causes of fishing cat mortality. This body of information helps in conservation planning to address the pressures that the species faces in Thailand.

Study Area

This study was initiated in January 2009 and was conducted in a 35 km^2 area (°56′54″E, 12°10′57″N) (Figure 2-1) that includes portions of Khao Sam Roi Yot National Park and the mostly agricultural and aquacultural areas adjacent to the park.

Khao Sam Roi Yot National Park was designated in 1966 (DNP 2013). The adjacent freshwater wetland was designated as Thailand's 11th Ramsar site in 2008 (IUCN). The vegetation of the area consists of scrubby mixed deciduous forest on karst formations, limited areas of mangrove and swamp forest, and active and fallow agricultural areas. Shrimp propagation ponds and rice paddies are tightly packed against the park's highly interdigitated boundary. Mangrove forest habitat along the eastern part of the study site is dominated by olive mangrove (*Avicennia marina*), large-leafed mangrove (*Rhizophora mucronata*), and small-leafed mangrove (*R. apiculata*). The western section of the study site is primarily agriculture, mainly rice paddies and aquaculture ponds, and is dominated by common reed (*Phragmites karka*), water chestnut (*Eleocharis dulcis*), reed grass (*Arundo donax*), and cattail (*Typha angustifolia*). Where these areas transition into fallow fields and seasonal rice production areas, grasses such as *Solanum indicum* and *Passiflora foetida*, along with swollen finger grass (*Chloris barbata*) and a variety of woody shrubs provide a mosaic of cover ranging from 1 to 3 meters in height. Occasional palms, tamarinds, and trees break up this low vegetation and anchor more structurally-developed patches of vegetation. Coconut plantations are located at the edges of the study site. The majority of the rice paddy fields in the area are burned in the dry season (December-March), although some of thicker areas are somewhat resistant to a full burn (Figure 2-10).

Methods

Capture and Immobilization

Fishing cats were captured between March 2009 and May 2010. I worked with a capture team consisting of veterinarians from the Monitoring and Surveillance Center for Zoonotic Disease in Wildlife and Exotic Animals (MoZWE), Faculty of Veterinary Science, Mahidol University and officials from the Department of National Park, Wildlife and Plant Conservation.

We used locally-constructed wire box traps measuring 72 cm x 20 cm x 26 cm for capture operations. These traps were designed after the Tomahawk Deluxe Single Door Rigid Live Traps. They were baited with chickens, which were. placed in the back of traps and separated from the captured cat so that they were not killed. Traps were checked every morning, and chickens were fed and watered every day. Bait animals were changed regularly to reduce the stress of captivity in the field. All traps were covered with vegetation to keep the chickens shaded and to minimize fishing cat wariness of the traps. Traps were open from approximately 1700 to 0700 hours and closed during the day to avoid capturing non-target animals, such as feral dogs or cats.

Capture and immobilization were conducted under close supervision of professional veterinarians from Mahidol University to reduce the potential for emergencies. Once a fishing cat was captured, the veterinary team tranquilized the animal, either immediately while it was in the trap, or by driving the cat out of the trap and into a net attached to the front of the trap. The drugs were a mixture of ketamine (6-10 mg per kg body weight) and xylazine (0.4-0.7 mg per kg body weight) (Grassman 2000, Swanson pers. com. 2008, and Kreeger et al. 2002), which were given by an intramuscular injection in the rear flank. Yohimbine (0.2 mg/kg) was used to reverse the xylazine (Kreeger et al. 2002). Yohimbine was administered after at least 30 minutes had elapsed since the last administration of ketamine. The reversal operation took place in a shady area and the animal's temperature was monitored.

I examined captured animals for external and skeletal injuries, recorded their weight, photographed them, and took blood, tissue, and hair samples. I conducted a dental exam to get a crude estimate of age with particular attention to tooth condition and wear.

Captured fishing cats were classified as adult (>1 year) or juvenile (<1 year) based on body size, size of external genitalia, and dentition. Adult animals were fitted with standard VHF signal collars made by Advanced Telemetry Systems (ATS) or Telonics (USA). The collars weighed approximately 145 grams, or 5% of adult body weight. For juvenile animals, we used expandable, temporary collars customized with an elastic band attached to the collar designed to break when stretched. The elastic band wore off after a month. Animals were also affixed with a single color- and number-coded ear tag. Captured animals were kept in a box trap and their temperature monitored until they were standing upright and moving around in their cages and then released at the site where they were captured.

Radio tracking

Animals were located at six-hour intervals. Radio tracking was divided into four discrete time periods: 0600-1200, 1200-1800, 1800-2400, and 2400-0600. Tracking during the day was done to locate resting sites, whereas, nighttime tracking (1800-0600) sought to locate habitat use and home range size of active animals. The signal ranged between 500 m and 1 km. We recorded each location of our position and the bearing to the animals radio signal. Cat positions were estimated by triangulation using three to four bearings. We took radio bearings that differed by at least 30 degrees to increase the accuracy of estimating the animal's position. Estimated locations of collared animals were calculated in the software program LOAS (Ecological Software Solutions, Inc., Sacramento, California) The mean location error of all locations was 72 m, and the error ranged from 30-300 m.

Data Analysis

<u>*Home range patterns*</u>

Home range has been defined as the "area traversed by the individual in its normal activities of food gathering, mating and caring for young" (Burt 1943). For this study, fishing cat home ranges and the core areas were estimated using data from the entire study period as well as separate wet and dry season data sets. Home range sizes were estimated using the 100% Minimum convex polygon method (Mohr 1947) and the 95% fixed Kernel estimator (Worton 1989). For the Kernel method, I chose the smoothing parameters based on 1) the minimum proportion of reference bandwidth that produced a contiguous home range polygon, or 2) the proportion of reference bandwidth that produced a home range polygon best reflecting an individual's actual space use (Kie J.G. 2010). Core areas were generated using 50% of the locations (Hooge et al. 2001).

Animal home ranges were calculated using ArcView (Version 3.3, Environmental Systems Research Institute, Inc., Redlands, California) and the HRE home range calculation extension (Rodgers and Carr 1998). Seasonal home-ranges were calculated for study animals with > 25 locations and 6 months of radio tracking per season. Prior to any analysis, I confirmed the robustness of home ranges by plotting home range sizes versus ascending number of locations for each individual to determine when home range size reached an asymptote (Odum and Kuenzler 1955). In all cases, I was able to confirm a point at which curves clearly plateaued.

Home range overlap was calculated using the following formula described by Poole (1995):

$$\frac{area\ of\ overlap\ \cdot\ 2}{(home\ range\ area\ of\ individual\ A\ +\ home\ range\ area\ of\ individual\ B)}$$

Habitat Use

I visually classified and made a hand drawn cover map from high resolution aerial photography. Vegetation classes included: 1) aquaculture, which was composed of shrimp and fish ponds; 2) rice fields; 3) coconut plantations, which had canals between each row of trees; 4) mangrove; 5) human habitation; and 6) limestone Karst. Although I determined the mean location error around all locations to be a radius of 72 m, I assumed that the habitat the animal used was the habitat at each point location. Each radio location was assigned to one of these cover types. Frequency of use of each habitat by each animal was converted to percent use to compare use among individuals. I also calculated the percent of each cover type in each animal's home range. Shrimp ponds were often 1 ha or larger and a large part of these ponds were not usable by fishing cats because they did not use water habitat except very near shore. At approximately 3 month intervals, ponds were drawn down. During drawdowns the entire land area of an aquaculture pond becomes available and was good foraging habitat. The use of rice fields varied with water levels and these were used more during the dry season.

Mortality

To establish the fate of all collared fishing cats I examined all carcasses to determine cause of death. In some cases, corroborating accounts from local residents assisted in determining the fates of study animals.

Results

Animal capture and telemetry

From February 2009 to May 2010 I captured 17 fishing cats (10 males, 7 females) ranging in age) from 3 months to 6 years. Weights of males ranged from 6.6-12.7 Kg and females ranged from 3.25-11.5 Kg. One young male was considered too young to safely outfit with a collar and was released. All of the other 16 animals were fitted with a collar and released (Table 2-1).

Home range

I calculated home range and home range curves for the six animals which had 49 to 445 locations. The cumulative curve for adult males reached an asymptote at 27 locations for male M8 and 50 for M5. For adult females, F2's curve was still progressing at the location 98 then gradually climbed until location 190 before a rapid climb to 240 locations and then leveled off at 400 locations. The curve for F1 began to level off at location 58, gradually climbed to location 190, and then leveled off again. F4's curve leveled off at 100 locations, and F7's leveled off at 75 locations (Figure 2-2).

Overlap of male and female home ranges was not measured because the data for the sexes were collected at different time periods. However, adult male fishing cats generally had larger overall home ranges and larger core home range areas than adult females. The annual 95% fixed kernel home ranges of two males were 4.0 and 13.5 km^2; while adult female cats (n=4) had a mean annual home range of 3.85 km^2 (range 2.0-6.8 km^2). Male fishing cats also had a larger 50% kernel core home range area than females (1.5 km^2 versus 0.9 km^2) (Table 2-2). There is a high degree overlap in the overall home range of females (Figure 5); F4 and F1 overlapped at 23%, and F4 and F2 overlapped at 35%. However, no overlap occurred between F1, F2 and F7. Finally, there was no overlap of the 50% kernel core areas between any of the four females (Figure 2-3). Shifts in seasonal home range sizes occurred in both males and females but these were minor (Figure 2-4 to 2-8).

Only one male fishing cat survived long enough to be tracked in both the dry and wet seasons. So the wet season home range of the single male with sufficient location data was estimated using the 95% fixed kernel method and it was 12.6 km^2; the dry season home range was 8.9 km^2. The mean wet season home range for females was 3.5 km^2 (range 3.0-4.4 km^2), and mean dry season range was 3.2 km^2 (range 2.3-5.3 km^2). One female, F4, had a larger overall home range (6.8 km^2) than the other females which all had home ranges of > 4 km^2 (Table 2-3). No overlaps of home ranges by the two males were calculated as they were not tracked during the same period.

The one male with sufficient locations for individual season analysis used a home range that was 11.7% larger during the wet season than during the dry season. Similarly, the home ranges of the four female cats averaged 10.8% larger in the wet season.

Using the MCP 100% method, males had a mean home range of 7.8 km^2, and females had a mean home range of 3.9 km^2. The home range for the one male was 10.8 km^2 during the wet season and 5.6 km^2 during the dry season. Mean female wet season home range was 3.2 km^2 and dry season range was 3.0 km^2.

Habitat Use

Of six cats studied in detail, three fishing cats used aquaculture in a higher proportion than was available (measured as total area of that habitat in each of these animals' home range); two used rice paddy more than available; and a sixth used rice paddy, aquacultural areas, and restored mangrove in more equal proportions. Although much less available than aquaculture and rice fields, coconut habitat was used more than it was available for two animals (Table 2-4).

Aquaculture was the most used habitat in both dry and wet seasons for two animals and it was the second most used habitat for 2 other individuals. Coconut plantation was used most by the male in the dry season and it appeared to be avoided by the same male in the wet season. Rice paddy was observed as the most used habitat for only one animal in both seasons.

Mortality

Of the 16 collared cats, 3 disappeared and may have dispersed or been killed. Of the other 13, five were poached, six died from unknown causes, two survived to the end of the study (Table 2-5). Carcasses of five of the cats that died were retrieved. In one case the poacher who shot an animal reported the cause of death when he returned its ear tag. Therefore, during the study period, there was 84% mortality of radioed cats.

Discussion

Home range

Overlap of male and female home ranges is reported for other cat species (Sunquist 1981, Sunquist and Sunquist 2002, Simcharoen et al. 2008, Simcharoen et al. 2014), and I suggest that fishing cats have the same spatial pattern of male home ranges that overlap those of females that is found in most cat species, and the same pattern of polygamy found is all species of cats (Sunquist and Sunquist 2002).

Three of the four females that were clustered in the northern part of the study area had no or low overlap of their home ranges. This observation also follows the typical pattern of female social organization reported for other cat species (Sunquist and Sunquist 2002). However, based on the age of these animals and their high degree of home range overlap, it was possible that F4 was the daughter of F2, who was the oldest female captured during the study. Despite the high overlap of F4 and F2 100% MCP and 95% kernel home ranges, it is interesting that none of the 4 females had any overlap of their 50% kernel core areas. Thus each of these cats had a secure area in their home range. It is not certain that other females did not live in this area where the four females occurred; however, it is unlikely that another female was a resident breeding animal in the northern section based on the general pattern of intra-sexual territorial behavior reported for other solitary felids (Sunquist and Sunquist

2002). It is also expected that an occasional female might pass through an occupied habitat even if the cats we radio tracked were highly territorial.

Evidence for slight seasonal shifts in home ranges was observed, but overall, the study cats remained within the same habitat types and the overall sizes of their home ranges and core areas showed no significant seasonal differences. The shifts for both sexes that were observed between the two seasons may correspond with different seasonal foraging conditions. Additionally, seasonal changes in land use activities by local people occurs in and around the National Park; animals typically avoided areas that lacked cover due to agricultural burning.

Habitat Use

Patterns of overall habitat use showed that aquacultural lands and rice paddies had the highest use by fishing cats. Within land encompassing fish or shrimp ponds, cat use varied with the status of individual ponds. When ponds were flooded, fishing cats could only hunt pond shorelines because they hunt from the shore line using the cover along the dike banks and then pounce of fish in shallow water. In contrast, when the ponds were drawn down or abandoned, fishing cat tracks were observed in high density, throughout the entire pond basin where they forage in a matrix of grass cover and shallow, remnant ponds where small fish are abundant and accessible. Farmers did not observe fishing cats raiding shrimp; this lack of predation on shrimp may be because fishing cats are not adept at hunting in deep water. Also scat analysis showed no shrimp remains (Chapter 1). There did not appear to be a seasonal pattern of use of aquaculture sites because water levels varied in both season as farmers periodically abandoned shrimp farming and drew down ponds.

The second most used habitat, rice paddy, had highly variable use among cats and seasons. This may also be a result of asynchronous farming of rice. Normally, rice is planted at the same time in a region, but in my study area it was not uncommon to let rice fields go fallow or be converted to aquaculture.

Coconut plantation was a relatively rare cover type but in the dry season it was the most used habitat type for M5 and used by F4 more than expected. These plantations may have been good foraging areas in the dry season because rows of trees were alternated with 2-3 m wide canals where fishing cats could efficiently forage (Figure 2-11 and 2-12).

Only one cat, F2, showed high use of the mangrove habitat as 97.5% of her locations were in this habitat type; M5 and F7 also used mangrove habitat but to a lesser degree. Mangrove restored areas provided food and also safety because they were characterized by dense shrubby cover and were located mainly within the boundary of the National Park.

Overall it appeared that fishing cats readily used aquacultural sites, rice paddies and coconut plantations and mangroves. Because habitat patches were difficult to measure and they occurred in blocks larger than fishing cat home range size, fishing cats may not have freely selected the array of habitats. Furthermore, the issue of scale combined with the likely territorial behavior of fishing cats does not allow animals to exercise third order habitat selection. Habitat that was not used was quite distinct. Limestone hills were strongly avoided likely due to sparse cover, no water and limited prey. Villages were also avoided as cover was limited and humans often shoot at fishing cats. Individually, the four preferred habitats appeared quite different, but all had escape cover that provided security from human hunting and aquatic edges that was preferred habitat for foraging.

Mortality

The major cause of fishing cat mortality recorded in this study was human activities (poaching and retribution killing) and it occurred primarily on private land outside the National Park. People living in this area were forthright in reporting that they killed and ate fishing cats. Poaching techniques were typically shooting or snaring, although poisoning was used as retribution for depredation on poultry. Geographic and demographic expansion of this population from protection in the Park to the neighboring human dominated landscape is likely limited by poaching.

The combination of habitat loss and direct killing of cats is the most serious threat to long term survival of the fishing cat population in my study area and likely elsewhere in Thailand.

Management implications

The primary threat to fishing cats in this study area is direct killing as retribution for real or perceived depredation of chickens. Local residents also killed animals for food or captured them to sell as pets. Fishing cats have relatively small home ranges and prey availability does not appear to be a problem for the cats Therefore, the priority management strategy should focus on reducing poaching and providing materials to farmers to build fishing cat proof housing for chickens.

A follow up long-term study that combined research on ecology and behavior of fishing cats in the Khao Sam Roi Yot area would provided additional information on age of first reproduction, litter sizes, age of dispersal, distance travelled and habitat used by dispersing young, and survival of different age and sex classes which would help management planning. But more importantly it would also serve as a vehicle changing attitudes and behavior of local residents through a mixture of educational programs and outreach activities. For example, this research could provide an opportunity for schools and local youth groups to participate in research and conservation programs not only for fishing cats, but also addressing ecological services and coastal zone management. This approach would provide important experiential learning opportunities for young people and engage them conservation.

Tables and Figures

Table 2-1. Fishing cat capture and telemetry effort, including the fate of each cat.

Cat ID	Capture Date (d-m-y)	Weight (kg)	Estimated Age	Last located (d-m-y)	Fate	Carcass retrieved	Number of Locations
M1	7-02-09	weight not recorded	3 months	18-02-09	unknown		27
F1	18-02-09	3.25	1 year	12-11-10	survived to end of study		445
F2	20-02-09	7.75	6 years	9-08-10	died (cause unknown)	1	289
M2	16-05-09	6.6	4 years	31-05-09	poached	1	10
F3	16-05-09	8.2	1 year	18-06-09	died (cause unknown)		25
M3	16-05-09	7.1	3 years	6-12-09	died (cause unknown)	1	14
M4	2-08-09	8.7	>4 years	19-08-09	poached	1	22
F4	15-08-09	10.7	2 years	31-05-10	died (cause unknown)	1	182
F5	29-08-09	9.4	>1 year	3-10-09	unknown		18
M5	29-08-09	8	3 year	8-02-10	poached		75
F6	30-08-09	11.5	7-8 months	5-08-09	died (cause unknown)		7
F7	31-08-09	4.2	1 year	5-06-10	survived to end of study		205
M6	12-08-09	8.5	>2 years	22-09-09	poached		12
M7	12-12-09	12.7	3 years	29-12-09	poached		10
M8	30-04-10	13	6 years	11-07-10	died (cause unknown)		49
M9	1-05-10	11	2 years	9-10-10	unknown		8

Table 2-2. Home range and core area estimates (km^2) for combined seasons of six radio collared fishing cats. MCP100 = Minimum Convex Polygon using all locations, 95% FK = Fixed Kernel using 95% of locations, MCP50 = 50% of points.

		MCP 100		**MCP 50**		**FK 95**		**FK 50**	
Cat ID	**No. mths**	***No. loc***	**(km^2)**	***No. loc***	**(km^2)**	***No. loc***	**(km^2)**	***No. loc***	**(km^2)**
Males									
M5	4	*75*	11.66	*71*	2.83	*75*	13.53	*75*	3.05
M8	3	*49*	3.99	*47*	0.41	*49*	4.01	*273*	0.9
Mean			**7.825**		**1.62**		**8.77**		**1.975**
SD			**5.42**		**1.71**		**6.73**		**1.52**
Females									
F2	20	*404*	3.07	*258*	1.52	*404*	3.28	*258*	0.92
F1	22	*275*	2.1	*261*	0.58	*445*	1.98	*268*	0.51
F4	10	*182*	8.14	*173*	0.84	*178*	6.78	*105*	1.36
F7	9	*205*	2.47	*195*	1.01	*205*	3.34	*133*	0.76
Mean			**3.95**		**0.99**		**3.85**		**0.89**
SD			**2.83**		**0.4**		**2.05**		**0.36**

Table 2-3. Seasonal home range sizes determined by 95% fixed kernel and 100% MCP.

		Wet Season			Dry Season	
Cat ID	***No. loc***	**95%FK (km^2)**	**MCP 100 (km^2)**	***No. loc***	**95% FK (km^2)**	**MCP 100 (km^2)**
M8	46	12.55	10.75	29	8.9	5.66
F2	153	3.08	2.91	119	2.26	1.98
F1	103	1.72	1.81	171	2.13	1.86
F4	52	4.42	6.51	129	5.3	5.86
F7	48	3	1.73	157	3.25	2.35
Female Mean		**3.06**	**3.24**		**3.24**	**3.01**
Female SD		1.1	**2.25**		1.46	**1.91**

Table 2-4. Percentage of habitat used vs. habitat available (based on counts of locations and proportion of habitat type in each animal's home range).

Cat ID	Aquaculture		Coconut Plantation		Human Settlement		Limestone Hill		Mangrove		Rice Paddy	
	Obs	Avail	Obs	Avail	Obs	Avail	Obs	Avail	Obs	Avail	Obs	Avail
M5	44.74	41.27	21.05	14.52	1.32	2.16	0	3.64	13.16	17.11	19.74	21.3
M8	30.43	38.08	6.52	8.94	0	1.22	0	5.9	2.17	2.77	60.87	43.09
F2	2.42	6.65	0	0	0.35	0.3	0	22.53	97.23	70.52	0	0
F1	30.24	34.94	1.1	2.14	0	0.76	0	5.54	7.51	6.69	61.15	49.94
F4	58.01	41	8.29	1.35	0	0	0	3.39	11.6	18.83	22.1	35.43
F7	66.67	48.07	0	0	0.49	6.49	0.49	22.23	32.35	23.21	0	0

Table 2-5. Summary table of animal captured and their fate.

	Poached	*Died (cause unknown)*	*Unknown Fate*	*Survived to end of study*	*Total Individual s*
Number	5	6	3	2	16
%	31.25	37.5	18.75	12.5	100

Figure 2-1. Study area in southern Thailand: Khao Sam Roi Yot National Park and surrounding areas.

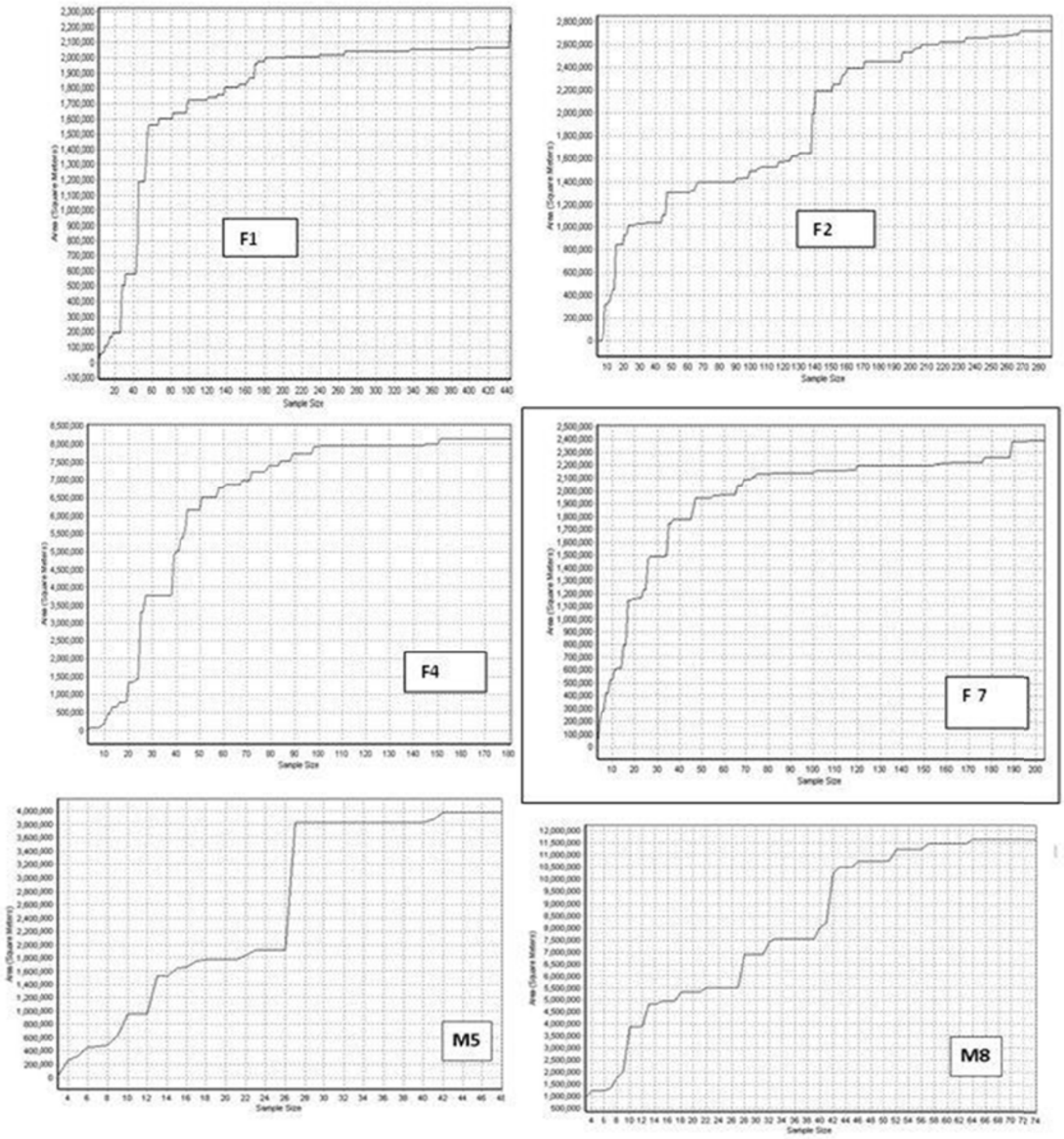

Figure 2-2. Cumulative home range curves of six fishing cats.

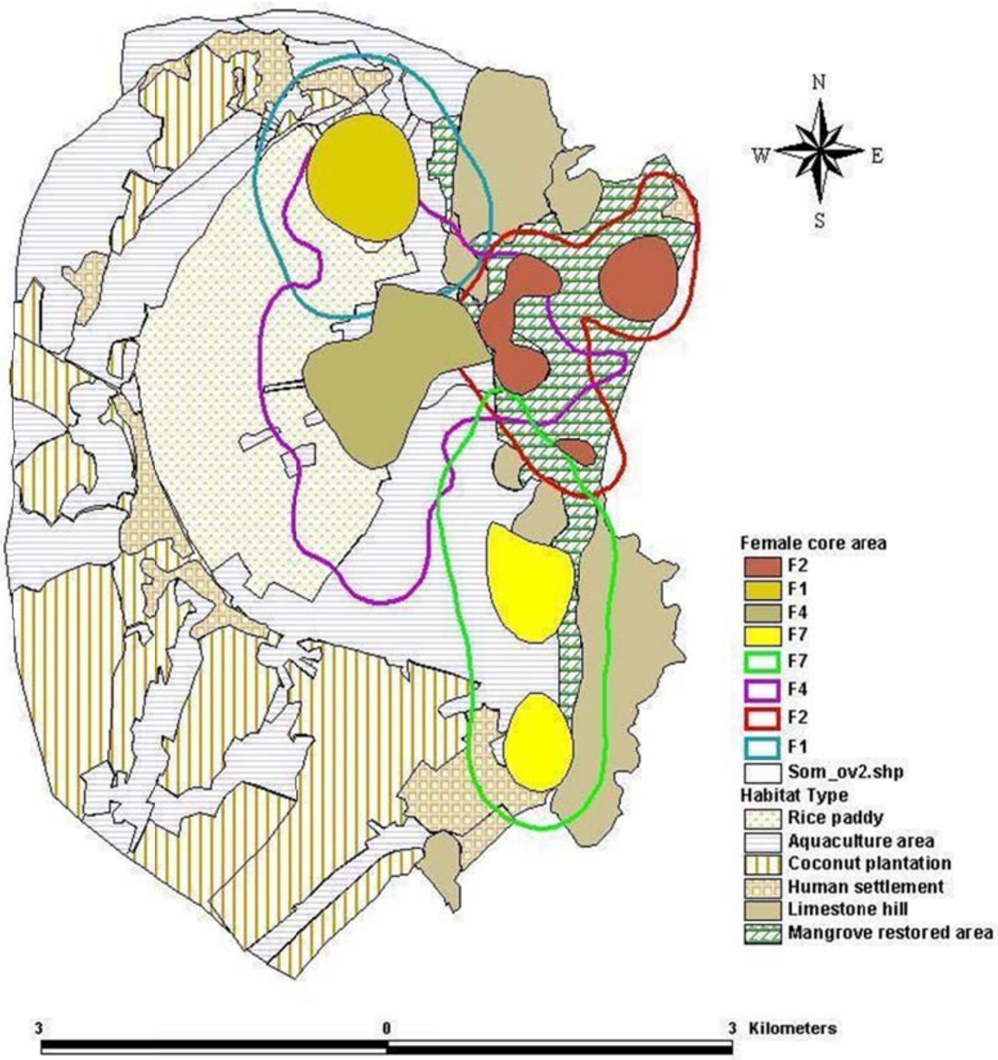

Figure 2-3. 95% and 50% fixed kernel home range of 4 adjacent female fishing cats. F1, F2, and F7 had no or very little overlap among themselves, but F1 and F2 had a high degree of overlap with F4. There is no information on the genetic relationship of these animals.

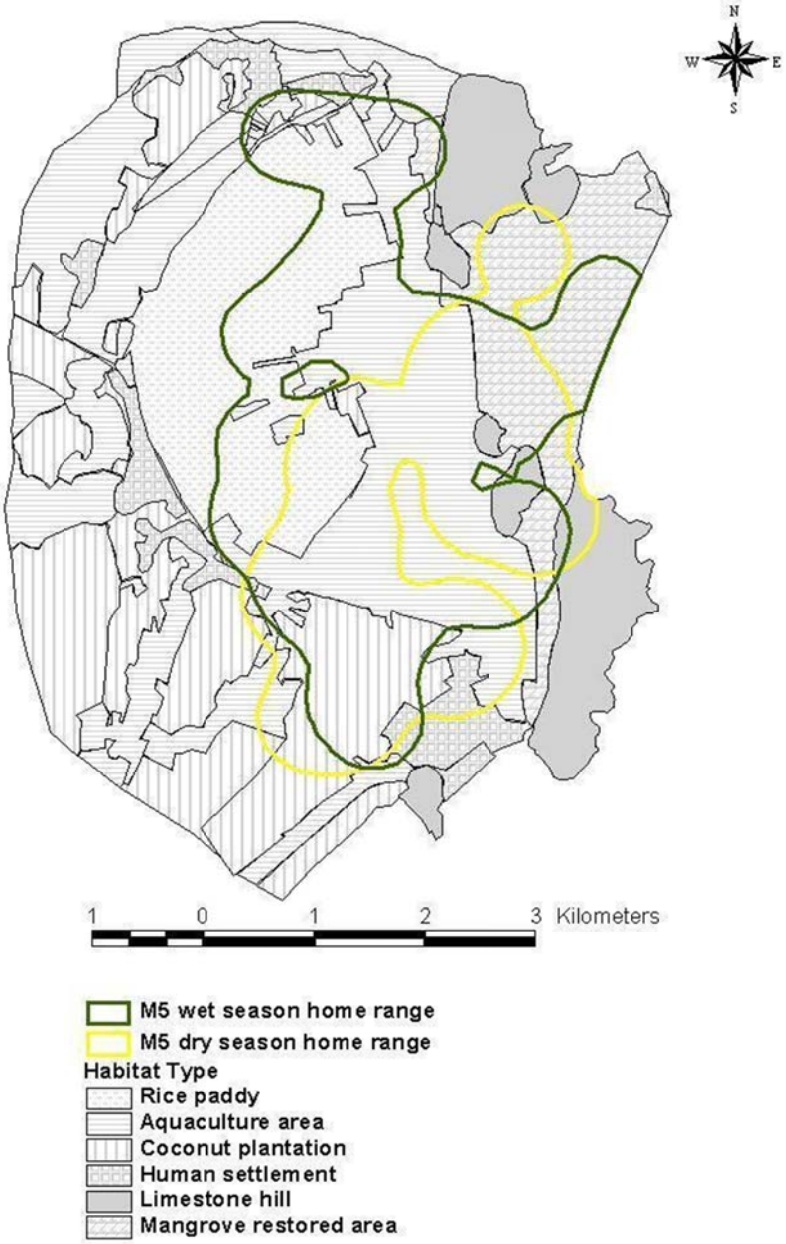

Figure 2-4. Seasonal Shift in Home Range of M8.

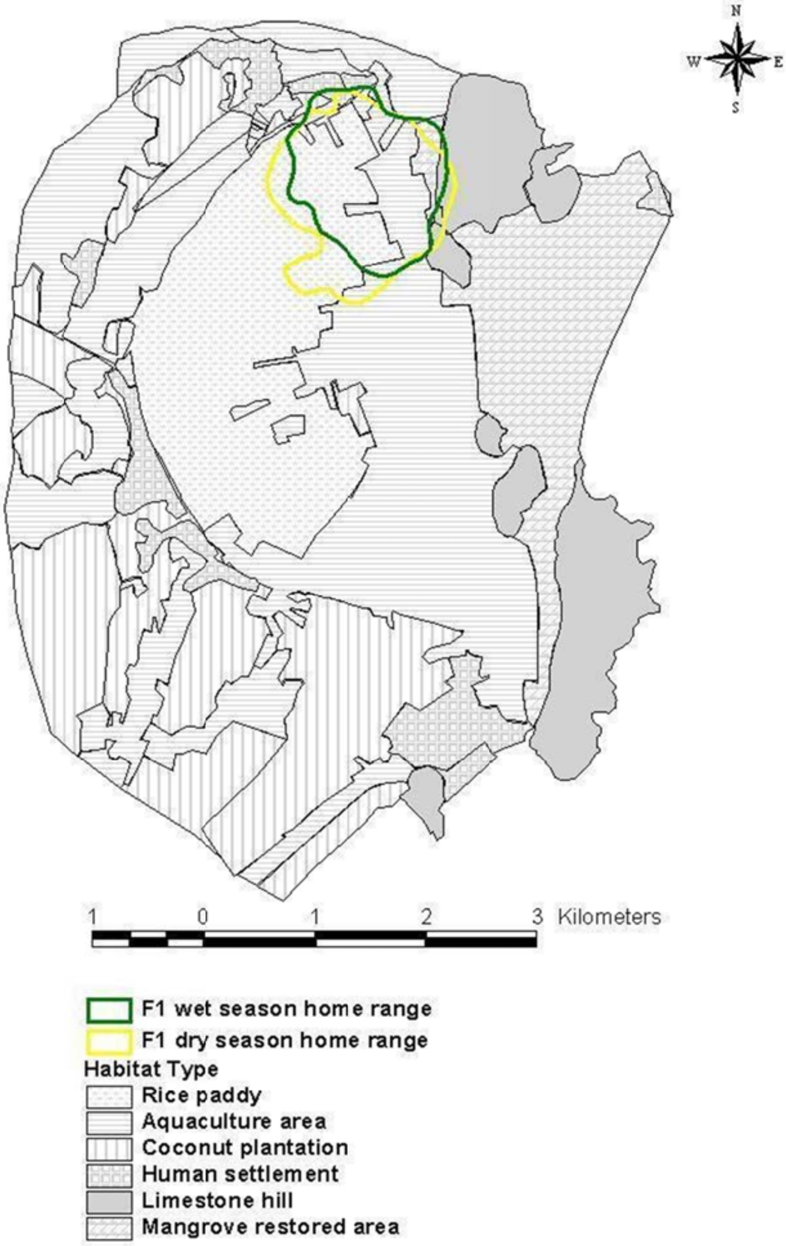

Figure 2-5. Seasonal Shift in Home Range of F1.

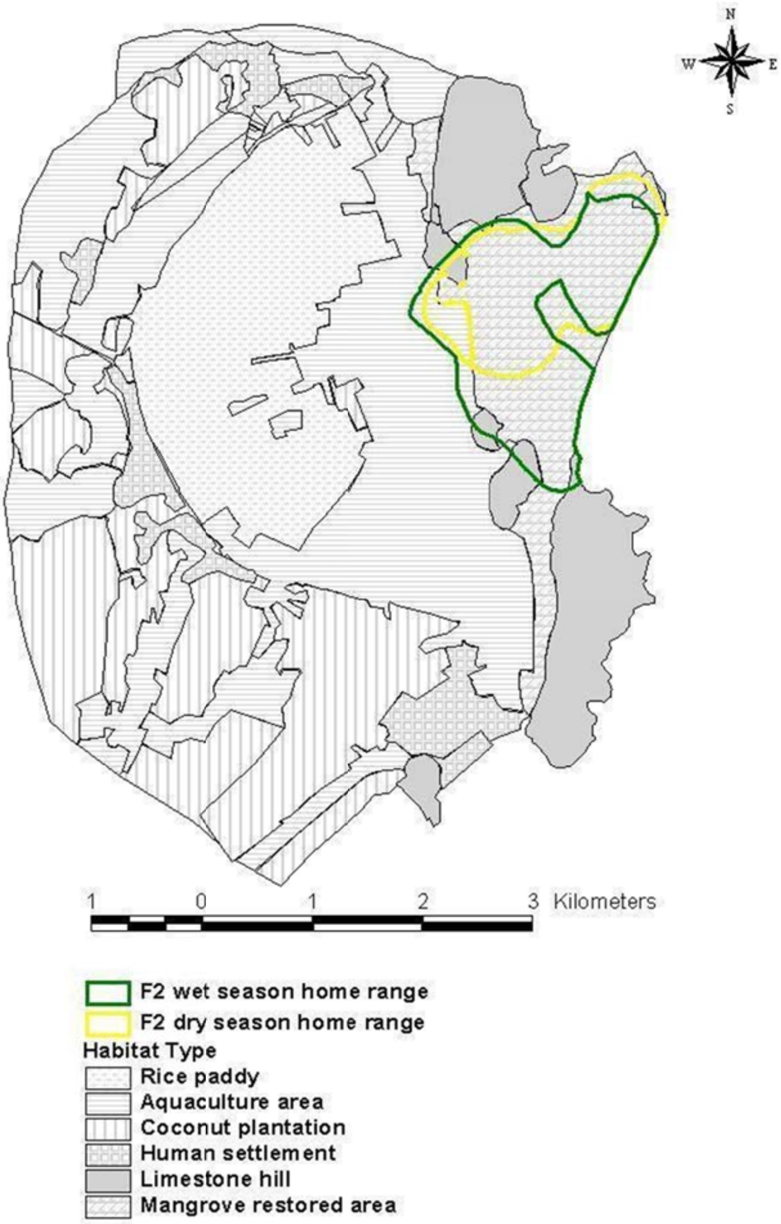

Figure 2-6. Seasonal Shift in Home Range of F2.

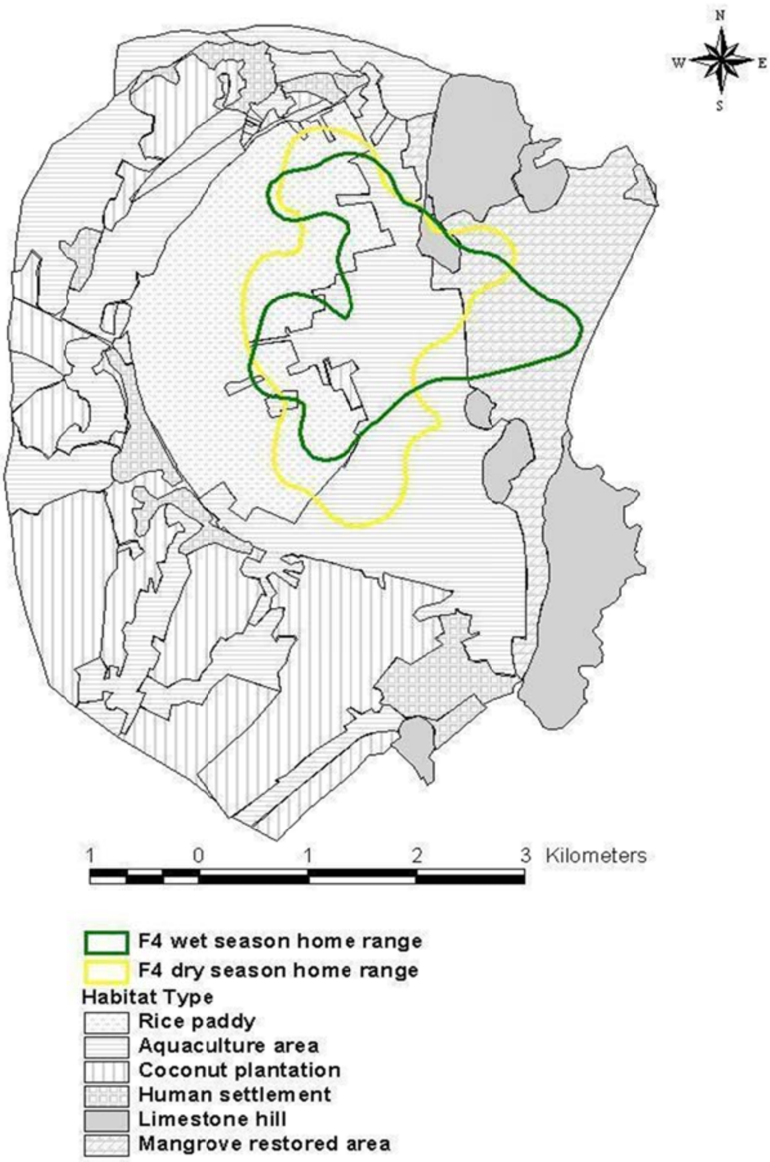

Figure 2-7. Seasonal Shift in Home Range of F4.

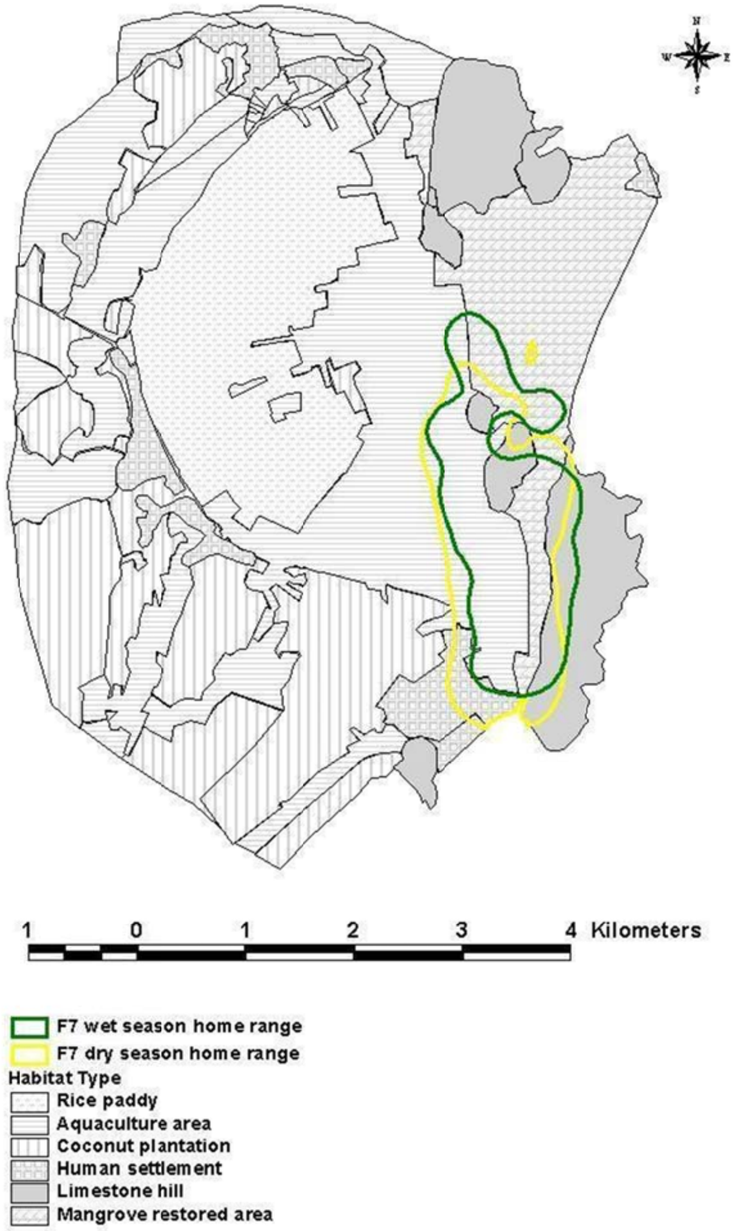

Figure 2-8. Seasonal Shift in Home Range of F7.

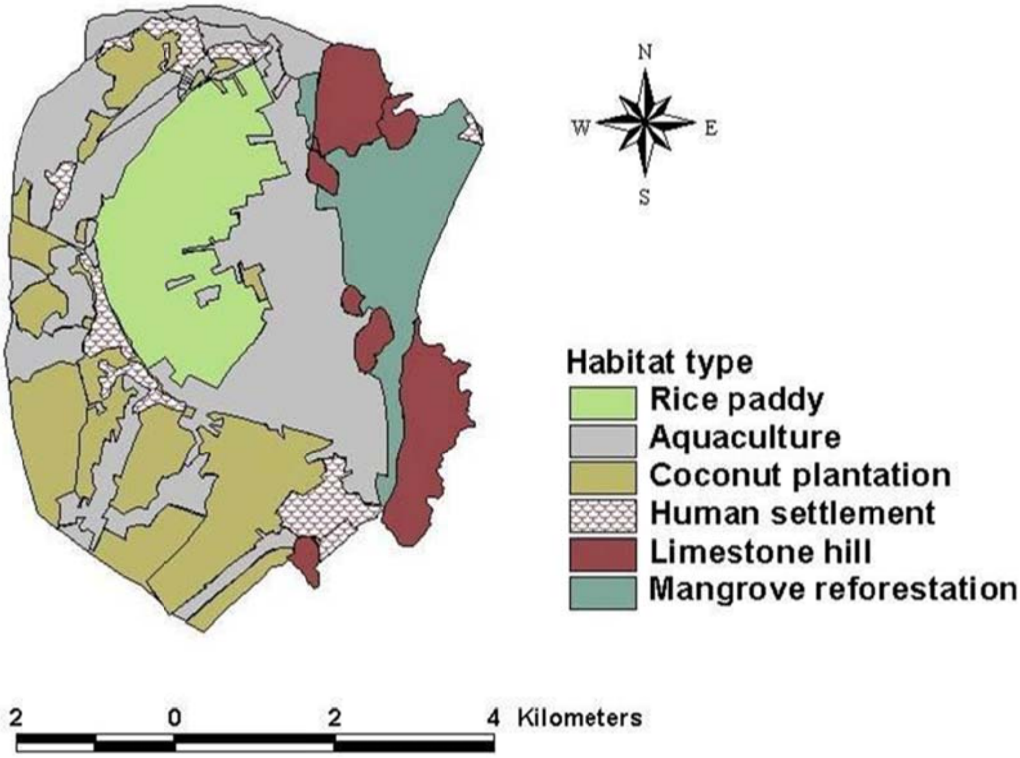

Figure 2-9. Habitat types in the study site.

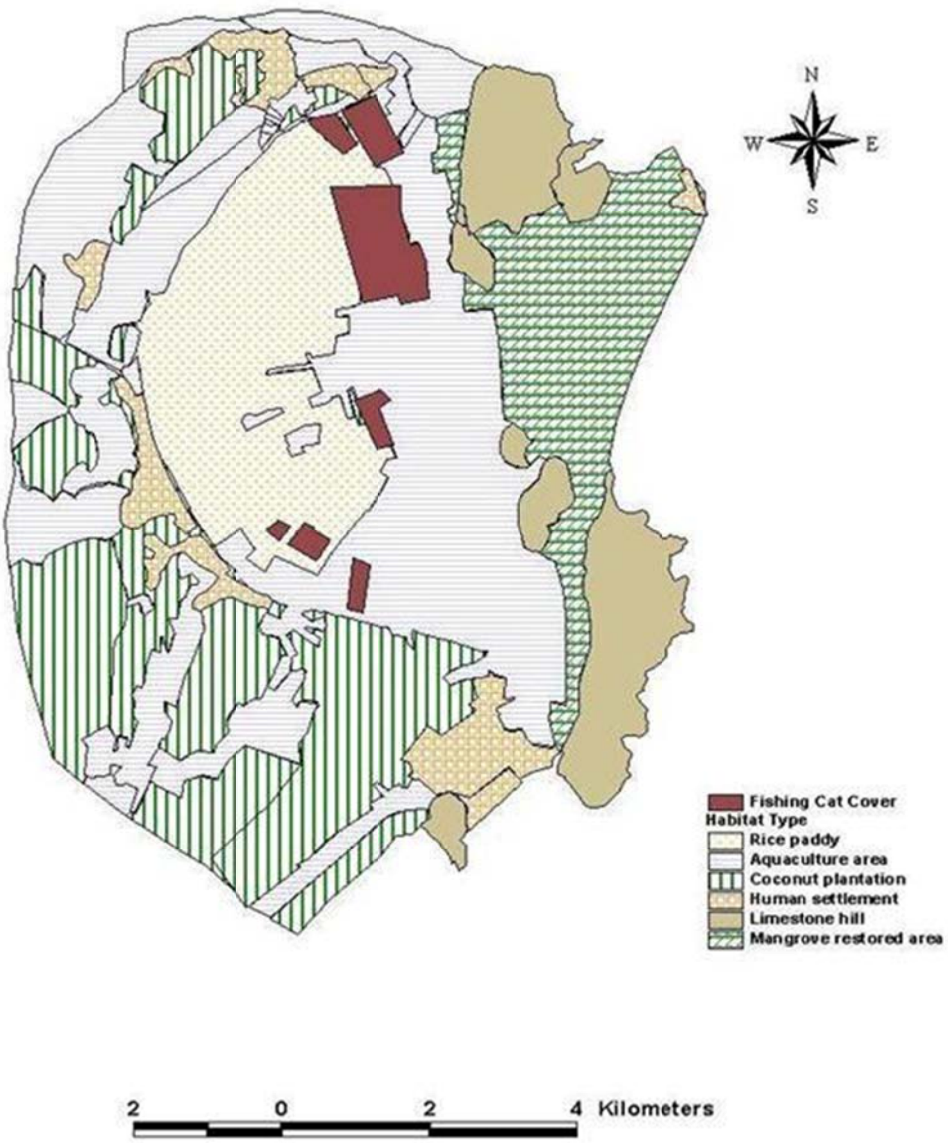

Figure 2-10. Fishing cat cover within the study site.

Figure 2-11. Aerial photo of habitats in study site showing rice paddy (middle) surrounded by aquacultural areas.

Figure 2-12. Coconut plantation within the study site

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