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REVIEW ON BEARCAT, *Arctictis binturong*, LITERATURE

EXTRACT of the THESIS

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TABLE OF ABREVIATIONS

2-AP : 2-Acétyl-1-pyrroline
ACTH : Adréno Cortico Trophic Hormone
AZA : Association of Zoo and Aquarium
CRH : Cortisol Releasing Hormone
CITES : Convention of Washington on the international trade of threatened species
EAZA : European Association of Zoo and Aquarium
EEP : Europäisches Erhaltungszuchtprogramm (Raising program for endangered species)
ELISA : Enzyme-Linked Immunosorbent Assays
EIA : Enzymo-immunoassay
ESB : European Studbook
GC : Glucocorticoïdes
HSI : Habitat Suitability Index
IUCN : International Union for Conservation of Nature
FCM : Fecal cortisol metabolites
UN : Unknown
PBS : Phosphate Buffered Saline
RIA : Radio-immunoassay
SCTAG : Small Carnivore Taxon Advisory Group
SD : Standard-deviation
TAG : Taxon Advisory Group
TMB : Tétraméthylbenzidine

INTRODUCTION

Nowadays, zoological parks play a capital role in species conservation, besides standing as entertainment and educational institutions. Indeed, some historical examples show the importance of their mission, such as the reintroduction of Prezwalski horses, *Equus przewalskii,* or of European bisons, *Bison bonasu*. To lead this mission, international raising programs were created. Unfortunately, the biggest challenge these institutions have to face is reproductive success; furthermore, they may face some reproduction issues in several species, which stem from several origins. The impact of stress in captive animals is increasingly studied and could indeed have a major influence on individual's fertility.

The bearcat, *Arcticis binturong* (Raffles 1921), is a singular species of the family of *Viverridae,* classified in the order of *Carnivora*. In addition present to exhibiting rare physiologic particularities, this species plays a major role within its ecosystem. Rather unknown to the general public, a lack of scientific knowledges persists on the bearcat's ecology and ethology. However, this kind of information could very well allow us to set up a conservation program for the species, which is listed as Vulnerable by the IUCN (Widmann *et al.*, 2008). If its survival as wild species is still outstanding due to various threats (e.g. deforestation, poaching), the maintainance of a captive population also raises a lot of issues, especially in terms of reproduction.

This is the very reason it seems necessary to improve knowledge on this species: in order to increase both the welfare of captive individuals and their reproduction rates.

This thesis includes two parts, but only the the first one, a review of the bibliography on bearcat, is presented here.

A. Taxonomy

The binturong, *Arctictis binturong* (Raffles, 1821), belongs to the order of *Carnivora*, suborder *Feliformia* and to family of *Viverridae*, which currently regroup all civets, except the fossa from Madagascar (*Fossa fossana*) which belongs to family of *Eupleridae*, recently set up as a fully-fledged family (Veron, 2007).

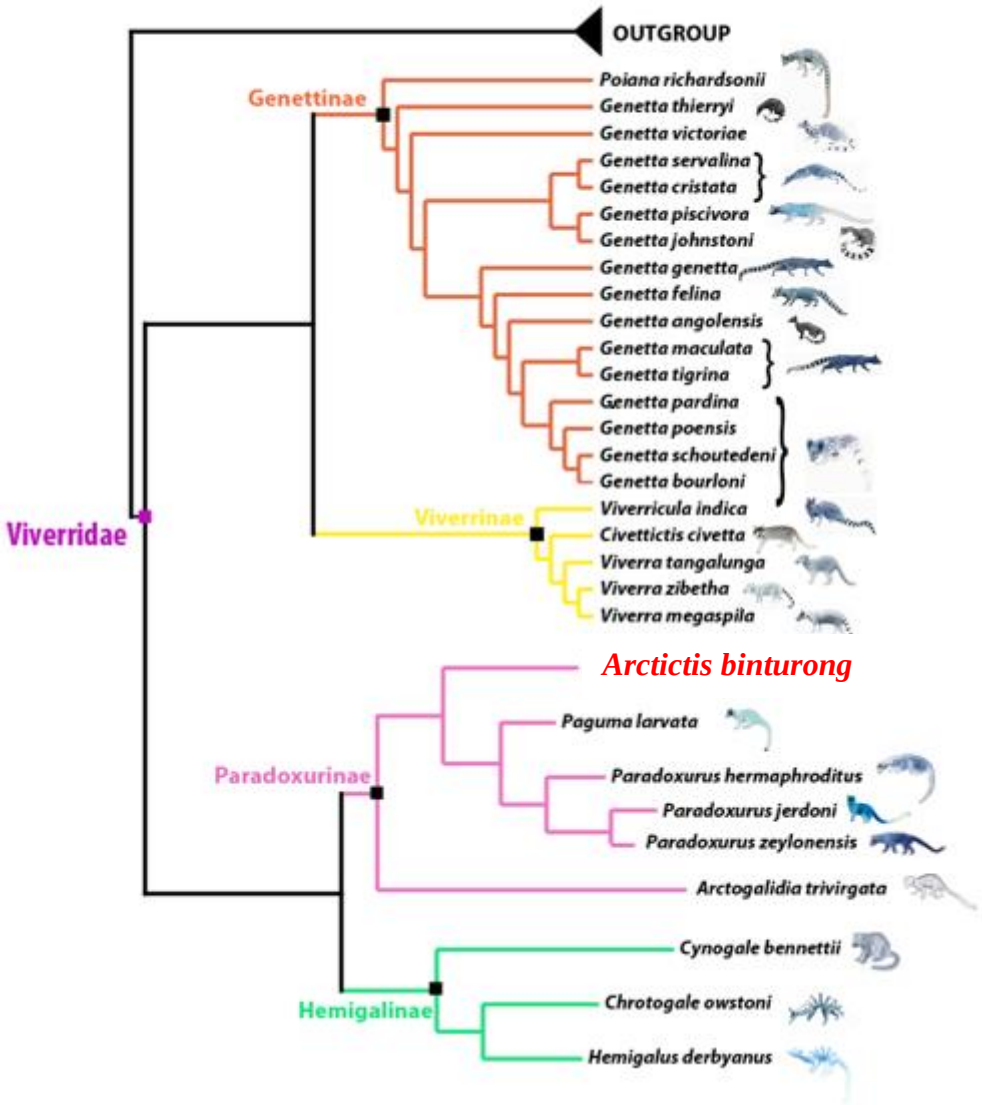
The phylogenetic relationships inside the *Feliformia* still raise numerous issues and yet no cladogram is accepted by the entire scientific community. The family of the *Viverridae* has been considered as a "catch-all" group for long time: scientists have placed in it each species that do not belong to either *Felidae* or *Hyaenidae*. That way of thinking, initiated by *Carnivora* specialists, implied a heteroclite grouping of morphotypes inside the *Viverridae*, which made diagnostic criteria very hard to establish. The sizes of those *Carnivora* are various, from 33 cm (*Poiana*) to 95 cm (*Civettictis*), with weights between 0.6 and 20 kg. The fur of the body can be spotted, striped or uniform and even sometimes ringed for the tail. They can be plantigrade or digitigrade and their claws can be entirely or not retractile. Dental formulas are variable inside this taxon (I3/3 - C1/1 - P3-4/3- 4 - M 1-2/1-2: between 36 and 40 tooth) (Gaubert, 2003; Veron, 2007).

Finally, the compared analysis of the bulla, initiated by Flower (1869) then followed by Hunt in the 70's, proposed the first phylogenetic characterisation of the *Viverridae*. More recently, the presence of perianal scent glands has become one of the major criteria for the inclusion of a species to this family (Flower, 1869; Hunt, 1974).

The subfamilies grouped inside of the *Viverridae* have also been long discussed and are still controversial, both for polymorphism reasons and also because of the lack of molecular markers. At present, this family includes three subfamilies of *Paradoxurines*, in which the beacrcat is found (Figure 1). This subfamily splits into five genera (*Arctogalidia*, *Macrogalidia*, *Paguma*, *Paradoxus* and *Arctictis*), which include all in all seven species. The bearcat is the only species from the genera *Arctictis* (Association of Zoo and Aquarium and Small Carnivore Taxon Advisory Group, 2007).

Only one subspecies, *Arctictis binturong whitei*, is well known and identified by morphological traits and genetic markers. This subspecies lives on Palawan Island, Philippines, and is smaller than other individuals from the mainland continents. Eight other subspecies have been described by Cosson *et al.* (2007) in a genetic study of the European captive population, but the studied sample is minimal and this description asks for confirmation and support by further genetic studies on animals in the wild.

Figure 1 : Phylogenetic tree of the family of the Viverridae (Patou et al., 2008). The sub-family of Macroglidae is missing.

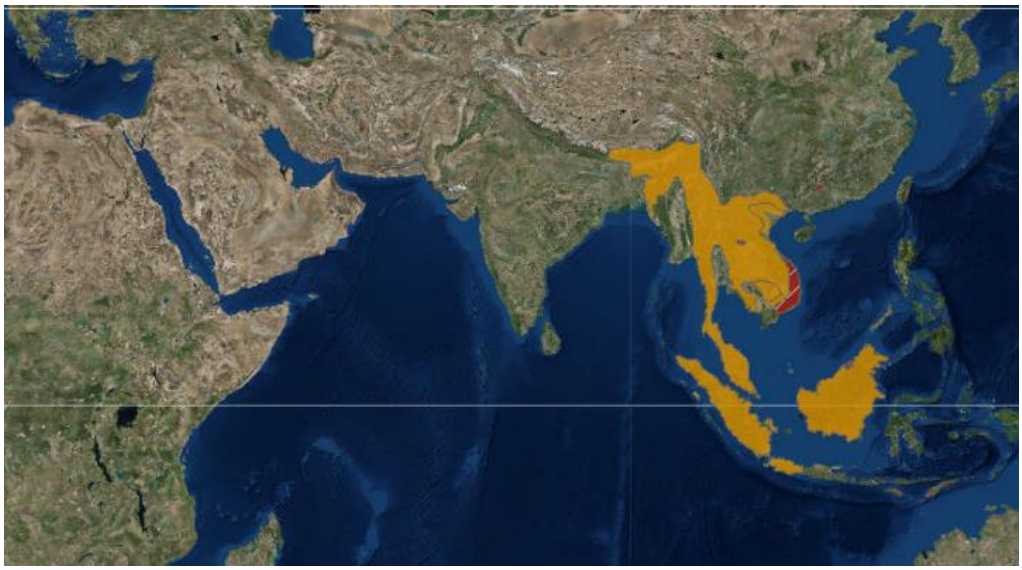


B. Ecology

Bearcats are found only in South-East Asia (Figure 2): their distribution range spreads from the South-East region of India to Sumatra Island in the South and includes Java Island, Palawan Island, Bangladesh, Malaysia, Myanmar, Nepal, Thailand, Viet-Nam, Laos, Cambodia, a part of Indonesia (Chutipong et al., 2015; Coudrat et al., 2014; Grassman, 2005; Grassman et al., 2005; Gray, 2014; Gupta, 2002). They have been considered to have disappeared from their natural environment in China since the 1980's; however, two hunters reported they might have killed bearcats during the 2000's in Hainan province. This suggests the bearcat may still remain, although in small populations, in some parts of China (Lau et al., 2010)

Figure 2: Distribution range map of bearcat *(Source : IUCN Red List maps).*

In yellow, the current distribution range. In red, the range where the binturong is considered to have disappeared from the wild. This species live only in South-East Asia.

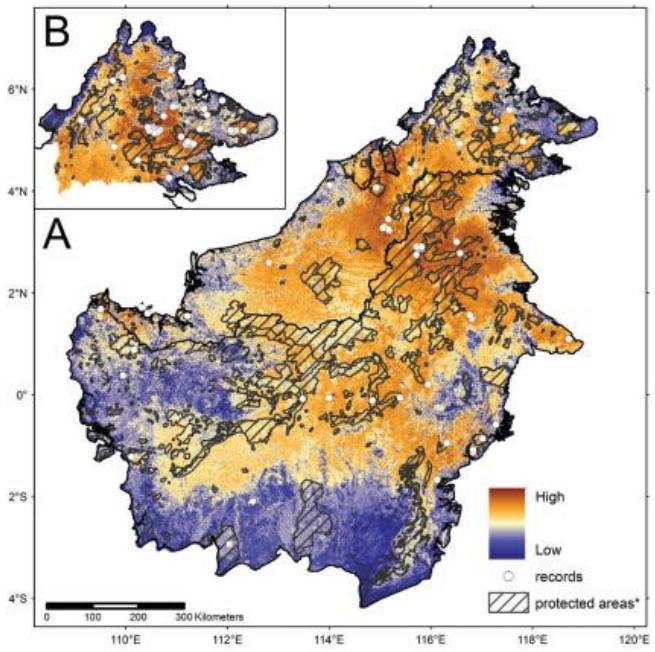


The bearcat is an arboreal species, living essentially in dense forests. It generally uses the upper part of the canopy (about 20 meters high) to find its food, the middle part (between 10 and 20 meters high) to rest and rarely goes on the ground, seemingly due to the presence of its predators (Grassman *et al.*, 2005). Indeed, natural predators of the bearcat are animals that spend a major part of their time on the ground: clouded leopard, *Neofelis nebulosa*; dhole, *Cuon alpinus*; tiger, *Panthera tigris;* and Temminck cat, *Pardofelis temminckii* (Chutipong *et al.*, 2015 ; Lam *et al.*, 2014). A recent study about binturong's nesting showed that the two studied individuals slept primarily on branches from big trees and remained close to the trunk. The tree species chosen were located only in the evergreen forest and had a dense vegetation cover, ranging from 76% up to 100% (Chutipong *et al.*, 2015). That means that binturong's habitat is restrained to forests with a sufficient crop cover located in lowlands or at low and high altitudes (Chutipong *et al.*, 2015 ; Rabinowitz et Walker, 1991 ; Semiadi *et al.*, 2016). On the other hand, scientists consider plantations, degraded forest, and bare fields unsustainable for this species. Indeed, binturong are rarely seen in secondary or exploited forests and none have been seen in plantations or complete cut forests (Mathai *et al.*, 2010 ; Rustam *et al.*, 2012 ; Yue *et al.*, 2015). This information, associated with data from camera-trapping, allowed Semiadi *et al.* (2016) to create a predictive map of sustainable territories for bearcats in Borneo Island (Figure 3). Thus, the center of the island still seems to be sustainable for the survival of the bearcat. On the opposite, coastal areas, which have more instances of degraded forests, especially on south of the island, are not habitable by the species. This map plays a major role in bearcat conservation plan by highlighting that the most important areas for bearcats might also become future protected areas.

The bearcat home range has also been studied. They seem to be quite restrained: from 2.4 km2 to 6.9 km2 in Chutipong *et al.* (2015) to 4.7km2 to 7.7 km2 in Grassman *et al.* (2005), with both studies taking place in Thailand. The studies also revealed that, on one hand the placement of nesting sites are widespread among the home range, with occurences even out of the home range, and that, on the other hand, there is an important overlapping between bearcats' home range and other species (e.g. 30% of home range overlapping with palm civet (Grassman *et al.* 2005)). Both studies show a weak territoriality of these animals, which indicated they are more tolerant of other species (Chutipong *et al.*, 2015 ; Grassman *et al.*, 2005 ; Nettelbeck, 1998).

Figure 3 : Predictive map of sustainable territories for the bearcat in Borneo Island, based on HSI model (Habitat Suitability Index) with the use of position records (Semiadi* et al., *2016).

A map corresponds to Borneo Island. B map corresponds to Sabah region (Malaysia) on Borneo Island.



C. Anatomy

1. Generalities

The bearcat sets itself apart from the other members of the *Viverridae* by the presence of its large size, its fur, and its long prehensile tail. An adult body can be between 60 and 90 cm long, with a tail up to 90 cm long. Its weight varies from 9 to 24 kg (Ahmad *et al.*, 2004 ; Moresco et Larsen, 2003) ; although, it is more likely to weigh around 12 kg in its natural environment in Thailand (Grassman *et al.*, 2006) and about 9 kg for the subspecies *Arctictis binturong whitei* in it environment from Palawan Island. It has a dense fur whose color ranges from dark black to light grey. Furthermore, the fur can include agouti hairs (Figure 4). The long black hair brushes behind its ears distinguish itself from the rest of its subfamily. Notably, it is the only *Carnivora*, alongside the kinkajou, *Potos flavus*, to have a prehensile tail, which serves as a real asset towards mobility in trees (Figure 5). It has five fingers on each hand and, like genus *Paguma* and *Paradoxus*, pads of the third and fourth finger are joined. However, the sole of the bearcat foot is naked up to the heel, which sets itself apart from those two genus (Pocock, 1933).

2. Digestive system

Although its diet is mainly set with fruits, the bearcat has kept its carnivorous teeth having prominent canines and carnassial tooth (Pocock, 1933). Identically, its digestive system has exhibits the carnivorous characteristics, having a acidic small stomach, a tiny or absent caecum, and a very little colon (Gahkod, 1878 ; Lambert *et al.*, 2014 ; Pocock, 1933). Moreover, it has the shorter and the less specialized digestive tract of its clade. The ratio between the length of its intestine and the length of its body is 2:1; furthermore, this ratio is the tiniest of all Carnivora, and its intestine has no sacculations or haustrations, which limits the amount of the surface dedicated to nutritional exchanges (McKenney *et al.*, 2014).

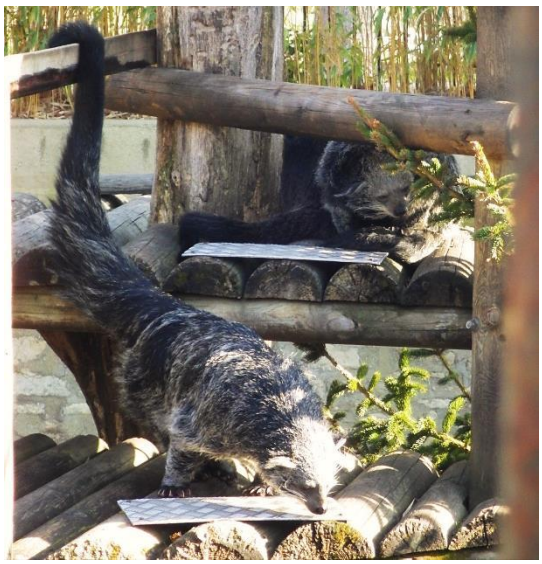
3. Reproductive system and perianal glands

Sexual dimorphism is not well pronounced. Although female genitals are highly developed with a peniform clitoris, distinguishing between both sexes quite difficult when they are young (Ahmad *et al.*, 2004 ; Moresco et Larsen, 2003 ; Story, 1945). Females have three pairs of teat, but the more cranial pair seems to be non-functional (Schoknecht, 1984).

As with other *Viverridae*, bearcats have perianal scent glands. Males have them between the penis and the scrotum and females have them above their vulva.

Figure 4 : Photography of Ekmatra, an adult bearcat,* Arctictis binturong*, at La Ménagerie du Jardin des Plantes, Paris (personal source)

Figure 5: Photography of a bearcat,* Arctictis binturong*, using its prehensile tail at La Ménagerie du Jardin des Plantes, Paris (personal source)



D. Physiology

1. Diet and digestive physiology

Although it is included in the order of *Carnivora*, the bearcat is mainly frugivorous : it eats mostly figs, *Ficus carica*, in its natural environment (Nakabayashi *et al.*, 2016). Despite this, it is still known to eats small prey such as birds or rodents (Ahmad *et al.*, 2004). Contradictorily with commonly found information, the bearcat is not a good fisher, thus it is quite rarely feeds itself with fish.

Despite the diet, the bearcat digestive system has kept carnivorous characteristics, which results in an underperforming digestion of fruits. A first study on two bearcats showed a limited fermentation process and evaluated the transit time to about 6.5 hours. This fast transit allows, according to the authors, a biggest amount of ingested food, thus a better assimilation of nitrogen, a low concentrate nutrient in fruits. However, a transit that goes too fast could be detrimental when very ripe food is missing and the carbohydrates intake is limited. As a result, the bearcat seems to have acquired hypometabolical adaptations: it might be able to make an important peripheral vasoconstriction which allows it to reduce its metabolism below basal rate of thermoneutrality. Furthermore, it might have subcutaneous fat for energy storage in order to compensate for a decreased intake of carbohydrates during low abundance seasons. However, such findings are only propositions and need further study on the subject to be confirmed (Lambert *et al.*, 2014). A second study on ten bearcats showed their digestive flora was not very diversified and counted only bacteria from the *Bacilli* class, which results from the carbohydrate-rich diet, which does not need the complex fermentation process to be digest (McKenney *et al.*, 2014).

2. Sent-mark secretions

The sense of smell seems to be one of the more developed senses in bearcat and that is the reason why the secretions of perianal scent glands and odorous molecules released in urine have a specific importance in this species.

Perianal glands secretions are essentially made up with short carboxylic acids and are used more for reproduction than as scent territory marking (Kleiman, 1974 ; Weldon *et al.*, 2000 ; Wemmer et Murtaugh, 1981). Volatile compounds released in urine and use as territory markings seems to be more abundant and varied. In addition there is a significant difference between sexes: males release more various compounds in their urine and in higher quantity than female. One of the most abundant compounds is 2-AP (2-Acetyl-1-pyrroline). Indeed, this molecule is well known to give the perfume of buttered popcorn and its presence explains why some people say bearcats smell like popcorn or flavoured rice. Although this molecule is produced by both sexes, it has been shown that there exists an association between androgenic blood rate and 2-AP level in urine: which could explain why this compound is more abundant in males' urine than in females' (Greene *et al.*, 2016).

3. Reproduction

At present, little information is available on bearcat's reproduction.

Breeding has been considered to be seasonal in the wild with two breeding periods: one at spring (March-April) and another one at autumn (October-November) (Ahmad *et al.*, 2004). Yet, births happen all year long in captivity (Mattoy, 2015).

A review of reproduction data from literature is summarized in Table 1. The length of the sexual cycle has been evaluated in captivity to be 82.5 ± 11.8 days (Wemmer et Murtaugh, 1981) and the gestation last between 88 and 99 days, under articles. Prolificity of this species is quite limited for a *Carnivora* as it has 3 cubs maximum in a litter. A study of the European Studbook on bearcats has been done with the use of the software Sparks (Table 2) on the total amount of data, which occurs between 1997 and 2016. Thus, in captivity, the younger individuals under reproduction were between one and two years old, which presents a first indication of the age of sexual maturity below 2 years. In a study of the international population of bearcat, Mattoy (2015) put the sexual maturity at 30 months for females and 27.7 months for males, as a result, those ages are a little bit older than stated in the European studbook. The average number of cubs in a litter is 1.9 according to the European Studbook, which agrees with other data in literature and with the data from the study of Mattoy (2015) who had an average number of 1.65 ±0.72 between 2004 and 2014.

Table 1 : Review on reproduction and cubs raising of the bearcat, Arctictis binturong.

The data in blue and thick are expressed as mean ± SD, in green and italic when it's a punctual or interval value(s).

Authors	Sexual cycle				Gestation		Cubs raising				
	Age of sexual maturity Male (months)	Age of sexual maturity Female (months)	Length of sexual cycle (days)	Time between two gestations (days)	Length of gestation (days)	Size of the litter	Birth weight (g)	Birth size (cm)	Opened eyes (days)	Apparition of teeth (days)	Weaning age (weeks)
Kuschinski (1974)					*96*	*3*	*333*	*37.5*	*9 to 10*	*21 to 28*	
Aquilina et Beyer (1979)					*92*		*283 to 340.5*		*4*	*34 to 41*	
Wemmer et Murtaugh (1981)	**27.7 ± 3.2**	**30.4 ± 3.7**	**82.5 ± 11.8**	**334.0 ± 27.2**	**91.5 ± 1**	**1.9 ± 0.1**	**307 ± 22.5**				
Abra (2010)					*88 to 99*	*1 to 3*			*10 to 11*	*27*	*40 to 63*

Table 2 : Data concerning the bearcat,* Arctictis binturong*, in captivity obtain by the analyse of the European Studbook with the help of the software SPARKS on data between 1997 and 2016.

Reproduction									Cub breeding				General data	
Age of the youngest animal to reproduce		Age of the oldest animal to reproduce		Mean age at first reproduction		Highest number of cubs for one individuals during its lifetime		Fastest time observed between two gestations	Mean litter size	Percentage of cub mortality (<30 days)	Percentage of cub mortality (<1 year)	Percentage of individuals raised by parents	Life expectancy at birth	Age of oldest individual
Female	Male	Female	Male	Female	Male	Female	Male							
1 year and 10 months	1 year and 7 months	17 years and 5 months	17 years et 2 months	4 years and 8 months	4 years and 6 months	37	37	82 days	1.9	31%	37%	83%	9.5 years	22 years

E. Behaviour

1. Social interactions

The tame personality of bearcats is a consensus in the scientific community, although scientists have yet to agree on the nature of their social interactions. Rozhnov (1994) observed them in the wild and noted they were solitary while observations from Murali *et al.* (2013) recorded observing groups of 2 to 3 individuals, without any record of social interactions. Otherwise, the bearcat could form a couple during the breeding season and groupings of mother and its offspring have already been observed in the wild (Ahmad *et al.*, 2004). Those differences could also be explained by the variety of the study locations and could expose some kind of plasticity of the species towards its environment.

In captivity, individuals are mainly alone or in couple. The female is often dominant in those dyads where she has a priority access to food and nesting (Abra, 2010 ; Wemmer et Murtaugh, 1981). Aggressions between individuals are nevertheless quite rare and with low violence; the bearcat could live in bigger groups according to AZA and SCTAG (Association of Zoo and Aquarium et Small Carnivore Taxon Advisory Group, 2007). This weak aggressivity could finally be under steroid hormones control. Indeed, according to Green et al (2016), males had more testosterone and androgen than female, but both sexes had the same level of oestradiols. Yet, in species with a female leadership, it is commonly found that females have increased levels of androgen, which is associated with a higher level of aggressivity (Petty et Drea, 2015). Furthermore, females normally have a higher rate of estrogen than males. So it is likely that the estrogen rate variation in males that explains the leadership of the female in bearcat, which is the opposite of what has been found in other species. Yet, the impact of a higher estrogen rate in males has been little studied: similar results has been shown in other species in which the reproduction was still normal and without demonstrate any link between behaviour and estrogen rate (Bubenik *et al.*, 1997 ; Petty, 2015). Further studies are thus necessary to confirm the hypothesis that the increase of estrogen in male bearcats is linked to a change of behaviour leading to a female leadership. Although this social system has only been shown in captivity, more research is required, especially of behaviour in the wild.

2. Activity rhythm

The bearcat's activity is still controversial. A first study lead by Rozhnov (1994) on a single captive individual showed the presence of increased activity peaks at night, and at different times depending on the season. In a second study taking place in Thailand, Grassman *et al.* (2005) equipped 5 males with radio-collars between September 1998 and November 2002. They noticed activity peaks between 4 a.m. and 6 a.m. as well as between 8 p.m. and 9 p.m., associated with a decrease of activity between 11 a.m. and 6 p.m. Furthermore, both articles are in agreeance that bearcats are crepuscular or nocturnal. Another study in wild used camera-trapping or direct observations, yet they do not have enough data to allow a reliable analysis of the activity rhythm of the whole population.

In captivity, one single study was lead on 3 bearcat for 250 hours at Anna Zoological Park. The peaks were between 9 a.m. and 12 a.m.. Agreeing with the observations of Kleiman (1974), the authors of this study concluded that the bearcats were diurnal (Arivazhagan et Thiyagesan, 2001).

Finally, it is still hard to conclude on the real activity of bearcats, although the data from captivity are quit complex to interpret because of the strong influence of human rhythm on individuals' behaviour.

3. Reproduction and young raising

Wemmer and Murtaugh (1981) studied sexual behaviour of 6 males and 3 female during 3 years. The oestrus of females was characterized by an increase of yelling and locomotion while agonistic behaviours decreased. The females showed mucus secretions on vulva, which they could use for scent marking. Males showed a significant increase of smelling behaviours and a decrease of defensive yelling. About breeding behaviour, it generally occurred several times, with few minute pauses, during several nights.

In captivity, it is recommended to separate the male before the parturition; yet, it has been observed in a few zoos that the male do participate to the raising of youth when it was not separated from the cubs (Abra, 2010 ; Association of Zoo and Aquarium et Small Carnivore Taxon Advisory Group, 2007). Furthermore, in the wild, male could show protective behaviours during the first two living weeks of the youth (Ahmad *et al.*, 2004).

As with the kitten, *Felis catus*, the cubs are born with tiny fur and blind, only to open their eyes a few days after the parturition. They show a significant preference for the inguinal teats, which could produce a better quality milk (Schoknecht, 1984). A few data on their raising has been collected in the literature and are summarized on Table 1.

F. Medical knowledges

1. Anaesthesia

There are only two publications on bearcat's anaesthesia. The oldest compares two protocols in which several molecules are used on captive individuals:

1/ Ketamine = 8mg/kg, medetomidine = 0.02mg/kg, butorphanol = 0.4mg/kg

2/ Ketamine = 4mg/kg, medetomidine = 0.04mg/kg, butorphanol = 0.4mg/kg.

Differences between those two protocols are minor concerning the change of physiological parameters (oxygen saturation, heart rate, respiratory rate, arterial blood pressure…) during anaesthesia. However, time to full recovery, described as the time before the animal stands, is shorter in the protocol 2 than in the protocol 1, respectively 11.6 ± 9.3 minutes and 42.7 ± 33.3 minutes. The second protocol presents a specific interest for use in captivity (Moresco et Larsen, 2003).

The second publication talks about the anaesthesia use on 8 wild bearcats of a protocol with ketamine and xylazine at the respective doses of 15 mg/kg and 1.3 mg/kg. After anaesthesia and obtaining the real weight of the animals the real doses injected were 19.7±4.1 mg/kg of ketamine and 1.3±0.4 mg/kg of xylazine. This protocol allowed a complete anaesthesia of individuals during in average 65.3±28.8 minutes. The induction and recovery time were respectively of 36.8±28.7 minutes. Moreover, authors mention the possibility to adjust the quantity of xylazine and also to use an antagonist of xylazine such as yohimbine or atipamezol in order to have of safer protocol. In the same study, the authors allude to the use of a protocol using tiletamine and zolazepam at the dose of 10mg/kg each without giving any information on the efficiency of the anaesthesia on individuals (Grassman *et al.*, 2006, 2005).

2. Diseases in zoological parks

Currently, major diseases referenced on the bearcat are canine distemper and toxoplasmosis. Canine distemper is an infectious disease that spreads easily in zoological parks. That is the reason why the vaccination of bearcats shows a specific interest. Sick individuals produced haemorrhagic diarrhea, anorexia, and nasal and eye discharge. This disease leads to the death of the animal in about ten days (Chandra *et al.*, 2000 ; Hur *et al.*, 1999). Regarding toxoplasmosis, the antibody has been found in three bearcats in Thailand and two more in the USA. Only one of this bearcat showed symptoms. It has been treated with triméthoprim-sulfadiazin for four days which lead to the healing of the individual. Because this parasite is zoonotic, it is very important to notice that bearcat can be asymptomatic carriers (Jensen *et al.*, 1985 ; Oronan *et al.*, 2014).

The bearcat can also be asymptomatic carriers of Chlamydia, which is also a zoonotic bacteria (Oronan *et al.*, 2014).

Other diseases diagnosed on bearcats are only clinical cases: herniated disc, ûlmonar microlithisasis, infectious necrosis of the myocardia and renal adenocarcinoma associated with hepatic adenocarcinoma and a pancreatic tumour (Bush *et al.*, 1976 ; Hollamby *et al.*, 2004 ; Klaphake *et al.*, 2005 ; Spriggs *et al.*, 2007). The two last afflictions were diagnosed during the necropsy.

The individual that suffered from herniated disc went through a hemi laminectomy but passed away due to surgical complications. Indeed, after surgery, the animal exhibited anorexia and vesical atony. The vesical atony was cured about ten days after the surgery, but it might be possible that the anorexia and stress created by the iterative handlings caused a cystitis, a pancreatitis, and a sepsis leading to the death of the animal 18 days after the intervention (Spriggs *et al.*, 2007).

The individual that suffered from pulmonar microlithisasis was first treated for dyspnoea and anorexia. After one month of antibiotics treatment, clinical signs were gone but the lung microlithisasis persisted on biopsy. It is quite possible that the animal suffered from a pulmonary infection and that the microlithisasis were only an incidental finding without incidence on the health of the individual (Bush *et al.*, 1976).

G. Conservation challenges

1. Role in its natural environment

Several studies on the role of the bearcat in its environment showed that it has a major impact on seed dispersal and germination. It is thus considered as a keystone species. Indeed, bearcat is a tall civet and can feed itself with bigger fruits than the other frugivorous civets. Moreover, on the opposite of Primates, the bearcat eats the whole fruit, with exception for the skin. Thus, seeds and fruits stones go through the gut which allows dissemination from a distance from the parental tree and an activation of the germination due to the action of digestives enzymes. The conservation of the Asian forest are thus partially linked to the conservation of bearcats (Colon et Campos-Arceiz, 2013 ; Corlett, 1998).

2. Threats

The contributing factor to the bearcat disappearing is deforestation, which has increased due to the plantations of oil palms, rubber trees and teak. The bearcat is also affected by poaching, for its meat, for pet trade or less often for its fur which can be used as an interior decoration (Corlett, 2007 ; Schreiber *et al.*, 1989). It is considered in Laos as a tasty dish and is reported to be easily caught, which means the bearcat is a species very sensitive to hunting (Duckworth *et al.*, 1999). Moreover, as with other civets, perianal glands are used in traditional Vietnamese medicine for healing mental diseases and for abortions (Roberton, 2007). In addition to those traditional threats, comes the threat of new trend: the civet coffee farms. Indeed, in these kinds of farms, the civets are fed with coffee beans but since they do not digest the seeds, the civet excrements are harvested and sold as coffee named "Kopi Luwak" after roasting. This coffee is at present the most expensive coffee in the world. Yet, this kind of captivity is not adapted to civets, which leads to a high mortality rate. The number of civets taken from the wild each year is estimated to be in the several thousands. That is the reason why those civet coffee farms are a rising threat for bearcats (D'Cruze *et al.*, 2014).

3. Abundance and IUCN status

Observations in the wild of this species are quite complex due to the fact it is an arboreal and nocturnal species, associated with dense living forests. Most of the studies aiming to evaluate Asian wild animal population abundance use the camera-trap set-up on the ground. Thus, photographs of bearcat are quite rare (Annexe 1). Increasing the number of photographs could be possible by changing the way camera-traps are set up: set up camera-traps where there are canopy gaps, or higher in trees, or in fruit trees, or place bait in front of them (Chutipong *et al.*, 2014; Semiadi *et al.*, 2016). The lack of information on this species associated to the important loss of its habitat lead the IUCN to put it as "vulnerable" on the Red List in 2008 (Widmann *et al.*, 2008).

4. In-situ conservation

Currently, there are few laws adopted by Asiatic governments to ensure the protection of the bearcat, except in Indonesia and in Vietnam where bearcats are fully protected (Lynam *et al.*, 2006 ; Nabhitabhata et Chan-ard, 2005 ; Shepherd, 2008). All the regulatory measures adopted for the bearcat are summarized in Table 3. This lack of statutory protection can be explained on the one hand by the lack of scientific knowledges and on the other hand by the fact that bearcats are unknown to the general public. Despite this, the number of output on the species has increased since 2014. Some studies have had a real scope on the conservation of the species such as the article of Semiadi *et al.* (2016), which describe the areas on Borneo which should be protected in order to ensure the bearcat safety. Attitudes are thus changing.

***Table 3 : Global protection and conservation laws on bearcat,* Arctictis binturong.** *Unknown data are noted UN.*

Country	Law	Measures	Set up date
International	Red list IUCN	Status « vulnerable »	2008
International	CITES	Annexe III : trade allowed with a specific exportation permit	1983
Bunei	none	none	-
Cambodia	UN	UN	UN
China	Red list	Status « in danger »	UN
Indonesia	Governmental regulatory measure n° 7/1999	Hunting and trade entirely forbidden	1999
Laos	UN	UN	UN
Malaysia	UN	Protected	UN
Sabah (Borneo, Malaysia)	Paragraph 2 of the Sabah wildlife conservation act	Hunting and owing allowed upon Sabah wildlife department authorization	1997
Sarawak (Borneo, Malaysia)	Wildlife protection ordonnance	UN	1998
Thailand	UN	UN	UN
Vietnam	Vietnam red list	Status « vulnerable »	2000
	Decree 32 IB	All exploitation (hunting, domestication, …) of the species is forbidden	2006

5. Ex-situ conservation

The *ex-situ* conservation plays a very important role, especially because the *in-situ* conservation is curently very little developed. That is the reason why the bearcat had its own European Studbook since 1997, which became a European Raising Program since 2016. Despite this, reproduction stays hard on captive bearcats as it is described in many papers (Aquilina et Beyer, 1979; Arivazhagan et Thiyagesan, 2001; Bulič, 1972; Gensch, 1963; Kuschinski, 1974; Wemmer et Murtaugh, 1981).

On the worldwide level, the birth-rate is very various between 2004 and 2014 with an average of 29.6 birth per year and a very high infant mortality rate (death before one year old) at 77% (Mattoy, 2015). This study showed also that births in March and births from young or under experienced mothers were statistically associated with a high infant mortality rate.

In Europe, there were 133 individuals at the first of January 2016 in 55 institutions. Two issues are raised in this population. Firstly, the sex ratio is imbalanced: 70 males, 50 females and 3 individuals which sex was still unknown. Secondly, some of the couple do not reproduce or cannot correctly raise cubs: the percentage of mortality before one month is an average of 30% according to the data from the European Studbook. Despite this, some couples are prolific, such as the couple from La Ménagerie du Jardin des Plantes of which produce a litter every year.

In captivity, there is a huge diversity of concerns when it comes to the results of reproduction. Those are possibly linked to the diversity of animal husbandry and the lack of knowledge on bearcat physiological and behavioural needs.

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ANNEX

Annex 1: Inventory of bearcat observations in the wild from literature

UN corresponds to unknown data in publications.

Location					Number of observation	Method	Date	Time	Study
Sites	**Region**	**Country**	**Habitat type**	**Altitude (m)**					
Chhlong	-	Cambodia	UN	UN	1	Camera trap	Between July 2003 and January 2006	UN	Gray, 2014
Phnom Prich Wildlife SaUNtuary	-	Cambodia	UN	UN	1	Camera trap	Between November 2001 and March 2007	UN	Gray, 2014
Phnom Prich Wildlife SaUNtuary	-	Cambodia	UN	UN	2	Camera trap	Between December 2011 and February 2013	UN	Gray, 2014
Phnom Tumpor	-	Cambodia	-	250	1	Captured in a village	UN	UN	Holden et Neang, 2009
Prey Long	-	Cambodia	UN	UN	1	Camera trap	Between April 2002 and March 2007	UN	Gray, 2014
Hornbill densities, Namdapha Tiger Reserve	Arunachal Pradesh	India	Humid tropical Evergreen Forest	590-680	10	Direct observation	Between February 2009 and March 2011	The morning (6am-11am), in the begin of afternoon (1pm-3pm) et the night (10pm)	Naniwadekar *et al.*, 2013
National park of Nandapha	UN	India	UN	UN	13	Direct observation	04 of December 2004	Night	Murali *et al.*, 2013

Tengapani RF	Arunachal Pradesh	India	Lowland forest	210	1	Direct observation	07 of February 2009	7am	Naniwadekar *et al.*, 2013
Trishna Wildlife SaUNtuary	Tripura	India	UN	UN	12	Direct observation	Between May and August 2001	Between 6pm and 20pm, and between 5 :30am and 7 :30am	Gupta, 2002
Bukit Soeharto Forest	Kalimantan, Bornéo	Indonesia	Secondary forest	107	2	Camera trap	Between March 2005 and June 2010	UN	Rustam *et al.*, 2012
The Natural Laboratory for the Study of Peat Swamp Forest	Kalimantan, Bornéo	Indonesia	UN	UN	1	Direct observation	2008	10am	Cheyne *et al.*, 2010
Sungai Wain Forest	Kalimantan, Bornéo	Indonesia	Primera forest	36	2	Camera trap	Between March 2005 and June 2010	UN	Rustam *et al.*, 2012
Hin Nammo	-	Lao	UN	UN	1	Camera trap	UN	UN	Duckworth *et al.*, 1999
Nam Chae Makfueng, Nakai–Nam Theun National Biodiversity Conservation Area	-	Lao	UN	828	1	Camera trap	UN	1:18am	Coudrat *et al.*, 2014

Nam Kading	-	Lao	Evergreen Forest	300-400	2	Camera trap	March-April 1995	5pm and 5:55am	Duckworth, 1997
Nam mon, Nakai–Nam Theun National Biodiversity Conservation Area	-	Lao	UN	UN	1	Direct observation	01 of March 2012	During the day	Coudrat *et al.*, 2014
Danum Valley Conservation Area	Sabah, Borneo	Malaysia	UN	UN	1	Radiotracking	From January 2013 to March 2014	During the night	Nakabayashi *et al.*, 2016
Deramakot Forest Reserve	Sabah, Borneo	Malaysia	UN	UN	UN	Camera trap	Between February 2008 and September	UN	Samejima *et al.*, 2012
Deramakot Forest Reserve	Sabah, Borneo	Malaysia	UN	UN	1	Camera trap	From July 2008 to January 2009	UN	Wilting *et al.*, 2010
Deramakot Forest Reserve	Sabah, Borneo	Malaysia	UN	UN	6	Direct observation	From July 2008 to January 2010	During the night	Wilting *et al.*, 2010
UN	Terengganu	Malaysia	UN	UN	3	Camera trap	Between April 2011 and March 2012	UN	Clements, 2013
UN	Perak	Malaysia	UN	UN	2	Camera trap	Between April 2012 and March 2013	UN	Clements, 2013
Lambir Hills National Park	Sarawak, Borneo	Malaysia	UN	UN	1	Camera trap	Between February 2004 and September 2004	UN	Azlan et Lading, 2006

Maliau Basin Conservation Area	Sabah, Borneo	Malaysia	Dipterocarpes Forest	280	4	Camera trap	Between January and May 2010	11am and 11pm	Brodie et Giordano, 2011
Sela'an-Linau Forest	Sarawak, Borneo	Malaysia	L	UN	4	Camera trap	Between January 2005 and September 2008	During the night	Mathai *et al.*, 2010
Sela'an-Linau Forest	Sarawak, Borneo	Malaysia	Logged Forest	UN	3	Direct observation	Between March 2004 and September 2008	morning	Mathai *et al.*, 2010
Ulu Segama Forest Reserve	Sabah, Borneo	Malaysia	Primary Forest	UN	3	Direct observation	Between January 1992 and Decembre 1993	During the night	Heydon et Bulloh, 1996
Western linkage	Perak	Malaysia	UN	UN	21	Camera trap	Between May 2012 and February 2013	UN	Clements, 2013
Htamanthi Night	-	Myanmar	UN	280	1	Camera trap	01 of September 1999	UN	Zaw *et al.*, 2008
Rakhine Yoma	-	Myanmar	UN	580	1	Camera trap	05 of January 2001	07 :10am	Zaw *et al.*, 2008
Tanintharyi	-	Myanmar	UN	60	1	Camera trap	20 of January 2002	4:13pm	Zaw *et al.*, 2008
Bumphabum	-	Myanmar	UN	800	3	Camera trap	01 of May 2001	During the night and the day	Zaw *et al.*, 2008

Hukaung Valley	-	Myanmar	UN	220	6	Camera trap	Between February 2001 and June 2005	During the night and the day	Zaw *et al.*, 2008
Naungmung	-	Myanmar	UN	1,2	1	Camera trap	24 aout 2002	6:52pm	Zaw *et al.*, 2008
Hala Bala wildlife saUNtuary	Bala	Thailand	Primary and logged forest	UN	7	Camera trap	Between November 2004 and October 2007	UN	Kitamura et Poonswad, 2010
Huai Kha Khaeng Wildlife SaUNtuary	-	Thailand	UN	UN	3	Direct observation	Between 1987 and 1989	UN	Rabinowitz et Walker, 1991
Khao Yai National Park	-	Thailand	UN	UN	24	Direct observation	Between February1992 and May 1996	During the day	Nettelbeck, 1998
Khao Yai National Park	-	Thailand	UN	UN	2	Camera trap	Between October 2003 and March 2007	UN	Jenks *et al.*, 2011
Phu Khieo Wildlife SaUNtuary	Chayaphum Province	Thailand	Evergreen Forest	UN	31	Capture for radiotracking	Between September 1998 and November 2002	-	Grassman *et al.*, 2005
Phu Khieo Wildlife SaUNtuary	Chayaphum Province	Thailand	Evergreen Forest	800-1000	2	Camera trap	Between February 2001 and July 2002	During the night	Grassman *et al.*, 2006

Phu Khieo Wildlife SaUNtuary	Chayaphum Province	Thailand	UN	UN	1	Camera trap	Between December 1997 and January 1999	UN	Lynam *et al.*, 2001
Thung Yai Naresuan Wildlife SaUNtuary	-	Thailand	UN	UN	2	Radiotracking	From December 2010 to January to 2012	-	Chutipong *et al.*, 2015
Cat Tien NP	Dong Nai	Vietnam	UN	UN	UN	Camera trap	Between 2006 and 2007	UN	Shih-Chih, 2009
Pu Mat NR	Nghe An	Vietnam	UN	UN	UN	Camera trap	Between 1998 and 1999	UN	Chutipong *et al.*, 2014

MEASURE OF THE HPA AXIS AND THE BEHAVIOUR OF A CAPTIVE SPECIES OF VIVERRIDE, THE BEARCAT, *Arctictis binturong*

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Summary:
The binturong, *Arctictis binturong*, is a threatened species living in the forest of South-East Asia. According to its decline, the raising programs in zoological parks play an important role, but they have to face some issues concerning the reproduction of this species. This thesis aimed first to make a complete bibliography of the binturong, and then aimed to set up a method to evaluate the stress of captive individuals. From this perspective, behavioural observations and assays of fecal cortisol metabolites (FCM) have been realized on 10 individuals from 6 French zoological parks. By the comparison of 4 extraction protocols, it appears that the FCM dosage on wet samples and with the use of a vortex is the most efficient method on binturongs. The next stage of the study with the assay of FCM from an individual towards its transfer from an institution to another allowed the biological validation of FCM as stress indicators in binturongs. Finally, the behavioural observations revealed that the majority of the group showed frustration by expressing anticipatory behaviour. Furthermore, the individuals with strongest anticipatory behaviours had low levels of FCM leads us highlight a possible correlation between chronic stress and a severe inhibition of cortisol excretion in binturongs.

Keywords: ARCTICTIS BINTURONG, VIVERRIDE, BEHAVIOUR, CORTISOL, STRESS, ETHOLOGY

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