Why Big Cats Are at High Risk of Extinction Due to Their Exceptional Predatory Abilities: What Conservation Strategies are Needed?

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Abstract

Cats have highly specialized physical adaptations for hypercarnivory, placing them among the most feared predators. Unique adaptations include strong skulls, sharp teeth, agile and muscular limbs, a taste only for meat, and hyper-retractable claws. These predator adaptations, which characterize the family Felidae, put Felids at high risk of human conflicts. Nearly all of the big cats have threatened or near threatened conservation statuses and 29 of the 37 Felidae species have decreasing population trends. Conservation strategies that consider the large habitats and herbivores required for these specialized predators are needed.

Keywords: Felidae, *Panthera*, hypercarnivory, Felid conservation

Cats evolved as apex predators and have remained relatively unchanged in physical structure for the last thirty million years (Chamoli & Wroe, 2011; Turner & Antón, 1997). Recently, the family Felidae of the order Carnivora has been facing major threats and dramatic population declines, largely due to human conflicts. As the International Union for Conservation of Nature (IUCN; 2013) identifies habitat loss as the greatest threat to mammals as a whole, Felidae species with small home ranges should have greater success in adapting to current pressures than those with large ranges.

In this paper, I review how physical adaptations of Felids lead to their roles as apex predators, and why these highly conserved predatory adaptations may now be contributing to the declines of Felidae species. I theorize that large species, such as those that belong to the genus *Panthera*, will be most at risk, due to the conflicts they have with humans. These large predators may occasionally kill livestock or attack people, creating animosity towards them. To explore this idea, this paper has a special focus on the genus *Panthera*, evaluating the ability of these top cats to adapt to current selective pressures, and discussing what conservation strategies need to be implemented to ensure

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their future survival. In order to develop effective conservation strategies, a thorough understanding of Felids specialized adaptations, phylogeography, current threats, and present status is needed (Barnett, Yamaguchi, Barnes, & Cooper,2006; O'Brien & Johnson 2005).

Predator Adaptations

Felids have many physical adaptations to provide them with extraordinary predatory abilities. Multiple skull and dentition adaptations give rise to Felids' ability for hypercarnivory, which is the ability to feed almost exclusively on meat. Common themes include many attachments for large craniomandibular muscles for bite strength and sharp-edged carnassial teeth for shearing prey (Diogo et al., 2012; Sicuro, 2011; Van Valkenburgh, 1991; Wroe, McHenry, & Thomason, 2005). In an analysis of 33 Felid species skulls, Sicuro (2011) identified five distinct patterns plus a generalized cat skull pattern (Table 1), which all had an "ecomorphological fit to hypercarnivory". Felid skulls are all adapted for hypercarnivory, but the size differentiation is likely to avoid niche overlap and prevent competition among species (Sicuro 2011). Large cats, such as those that belong to the genus *Panthera*, have a wide gape with strong canines and incisors that provide grip and strength when strangle-holding large prey (Meachen-Samuels & Van Valkenburgh, 2009). Felids may not have the strongest bite strength of all the hypercarnivores, as some members of the family Canidae have stronger bite strength when normalized to body mass. However, this in itself may be an adaption to hypercarnivory; cats have a shorter skull than dogs, resulting in reduced bite strength for some species, but providing better resistance to torsion forces created from struggling prey (Wroe et al., 2005).

In addition to skull and dentition adaptations for hypercarnivory, cats have many muscle adaptations. For close-up encounters, cats have powerful and flexible forelimbs to assist with holding and controlling struggling prey (Wroe et al., 2005). Diogo et al. (2012) compared head and neck muscles of the tiger (*Panthera tigris*) and serval (*Leptailurus serval*) to other eutherian mammals and found that the tiger and serval have more facial muscle structures, which is an ancient adaptation for carnivory.

One of the most unique adaptations separating Felidae from other mammals is loss of the ability to taste sugars (Li et al., 2005; 2006). Cats do not have a taste receptor for sweetness, due to pseudogenization of the sweet-receptor gene (Li et al. 2005). This pseudogenization of the sweet-receptor gene is not seen in the other main group in Carnivora, the Canids (Li et al., 2006). The lack of cravings for sweet carbohydrates contributes to cats' behaviours as top predators (Li et al., 2005).

A few families within the order Carnivora have the ability to retract their claws, largely for protection, but cats are able to hyper-retract their claws. This system allows for more spreading during protraction and both hook-shaped and blade-like claws that ultimately produces a more lethal weapon than is seen in other carnivores (Bryant, Russell, Laroiya, & Powell, 1996). Interestingly, cheetahs (*Acinonyxjubatus*) are an exception to this feature, as they do not have retractable claws (Russell & Bryant, 2001). Cheetahs instead have paw and claw adaptations for traction, contributing to their status as the fastest terrestrial mammal, a skill that is important for their hunting style in which they chase prey at high speed (Russell and Bryant 2001). This hunting method is opposed to that of other felids, which typically ambush their prey (Russell & Bryant, 2001).

Specialized cranial, muscle and dentition adaptations, loss of a sweet taste receptor, and retractable claws are only some of Felidae adaptations for hypercarnivory. Unfortunately, these unique characteristics that give rise to fierce hunters are creating a disadvantage for big cats in the modern world.

Table 1: Distinct Felidae skull patterns observed by Sicuro (2011) in an analysis of 33 Felidae species, and the corresponding genus or species that best represent these patterns.

Felidae Skull Pattern	Genus and/or Species
snouted/massive-headed	*Panthera*
round-headed small cats	*Leopardus colocolo, Leopardus geoffroyi, Leopardus guigna, Prionailurus bengalensis, Prionailurus rubiginosus*
tapering-headed	*Neofelis nebulosa, Herpailurus yagouaroundi, Prionailurus planiceps*
stout-headed	*Acinonyx jubatus, Panthera uncia, Otocolobus manul, Felis margarita, Felis nigripes*
low profile-headed	*Prionailurus planiceps*
generalized	*Lynx, Leopardus pardalis, Catopuma temminckii*

Recent Evolution

The family Felidae has little taxonomic diversification compared to other Carnivora families, such as Canidae (Chamoli & Wroe, 2011; Van Valkenburgh, 1991). Holliday and Steppan (2004) found that hypercarnivory specialization affects morphological diversity, particularly of the jaws and dentition, but not taxonomic diversity; thus, cats' evolutionary trajectories should not be limited. The youngest cats in Felid evolution are the smaller New World cats, such as the ocelot (*Leoparduspardalis*; Van Valkenburgh, 1991).

The best evidence of recent adaptations in Felids is observed in the clouded leopard (*Neofelisnebulosa*).

Christiansen (2008) performed a comparative analysis of the craniomandibular morphology of the clouded leopard and primitive sabercats (*Paramachairodus spp.*) that gave evidence of similarities between them and divergence between the clouded leopard and other large Felids. One such similarity was the elongated, blade-like canines known as saberteeth (Christiansen, 2008). Other extant Felid species are conical-toothed, exhibiting hypertrophied and blade-like upper canines, with reduced lower canines (Christiansen, 2008; Slater &Van Valkenburgh, 2008). Arguably, the sabertooth is not a progressive 'new' trait in cats, but simply a regression towards a familiar trait. In my literature review, the clouded leopards' convergence with primitive sabercats is the only known evidence of recent

Table 2: Population trends and IUCN status for the family Felidae. Adapted from IUCN (2015).

Species	Common Name	Status	Population Trend
Acinonyx jubatus	Cheetah	Vulnerable	decreasing
Caracal aurata	African Golden Cat	Vulnerable	decreasing
Caracal caracal	Caracal	Least Concern	unknown
Catopuma badia	Borneo Bay Cat	Endangered	decreasing
Catopuma temminckii	Asiatic Golden Cat	Near Threatened	decreasing
Felis bieti	Chinese Mountain Cat	Vulnerable	decreasing
Felis chaus	Jungle Cat	Least Concern	decreasing
Feilis margarita	Sand Cat	Near Threatened	unknown
Felis nigripes	Black-footed Cat	Vulnerable	decreasing
Felis silvestris	Wild Cat	Least Concern	decreasing
Herpailurus yagouaroundi	Jaguarundi	Least Concern	decreasing
Leopardus colocolo	Pampas Cat	Near Threatened	decreasing
Leopardus geoffroyi	Geoffroy's Cat	Least Concern	stable
Leopardus guigna	Guiña	Vulnerable	decreasing
Leopardus jacobita	Andean Cat	Endangered	decreasing
Leopardus pardalis	Ocelot	Least Concern	decreasing
Leopardus tigrinus	Oncilla	Vulnerable	decreasing
Leopardus wiedii	Margay	Near Threatened	decreasing
Leptailurus serval	Serval	Least Concern	stable
Lynx canadensis	Canada Lynx	Least Concern	stable
Lynx lynx	Eurasian Lynx	Least Concern	stable
Lynx pardinus	Iberian Lynx	Endangered	increasing
Lynx rufus	Bobcat	Least Concern	stable
Neofilis diardi	Sunda Clouded Leopard	Vulnerable	decreasing
Neofilisnebulosa	Clouded Leopard	Vulnerable	decreasing
Otocolobus manul	Pallas's Cat	Near Threatened	decreasing
Pardofelis marmorata	Marbled Cat	Near Threatened	decreasing
Prionailurus bengalensis	Leopard Cat	Least Concern	stable
Prionailurus planiceps	Flat-headed Cat	Endangered	decreasing
Prionailurus rubiginosus	Rusty-spotted Cat	Vulnerable	decreasing
Prionailurus viverrinus	Fishing Cat	Endangered	decreasing
Puma concolor	Puma	Least Concern	decreasing

Table 3: *Population trend, IUCN status, distribution and habitat tolerance for the family Felidae, genus Panthera. Adapted from IUCN (2015).*

Species	Common Name	Status	Population Trend	Distribution	Habitat Tolerance
Panthera leo	Lion	Vulnerable	decreasing	sub-Saharan Africa, India	broad
Panthera onca	Jaguar	Near Threatened	decreasing	South America (southern portion)	broad
Panthera pardus	Leopard	Near Threatened	decreasing	Africa, tropical Asia, Eastern Europe, Middle East	broad
Panthera tigris	Tiger	Endangered	decreasing	tropical Asia, Russia far East	restricted (forests)
Panthera uncia	Snow Leopard	Endangered	decreasing	mountains of Central Asia	restricted (alpine and sub alpine)

adaptations in the family Felidae, which suggests that they are not adapting widely or quickly enough to current selective pressures, further putting them at high risk of extinction.

IUCN Status

For the family Felidae, the International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species does species assessments for 37 members. Of those 37 species, seven are listed as Endangered, 10 are Vulnerable, and another eight are Near Threatened (Table 2; 3). This translates as 46 percent of species in the family Felidae under threat and another 22 percent nearly threatened (IUCN, 2015). Most of the Felidae species show a declining population trend (Table 2; 3). The only large cat that does not have a threatened status is the puma (Table 2). While the puma's population is decreasing, it is currently listed as Least Concern (Table 2), a status that may be due to the fact that it has the most expansive distribution of all the felids (O'Brien &Johnson, 2005). The only members of Felidae that show a stable population trend are small species, which supports the idea that larger cats are more vulnerable (Table 2).

Members of the genus *Panthera* represent the largest of the extant cats (Sicuro, 2011). The large cats, especially those of the genus *Panthera,* are currently among the most at risk Felidae species (O'Brien & Johnson, 2005). All five of the *Panthera* species have decreasing populations and threatened conservation statuses (Table 3). Notably, the two species with restricted habitats, tigers and snow leopards, are the most at risk, with an IUCN status of Endangered (Table 3).

Threats

For *Panthera spp.* habitat loss and human conflict are the biggest threats to survival (IUCN 2013). Tigers, an endangered species (Table 3), are probably the most feared cats, as they are well known for attacks on people (O'Brien & Johnson, 2005). Human conflicts involve retaliation for killing livestock, persecution, poaching, and trophy hunting (Datta, Anand, & Naniwadekar, 2008; Hoogesteijn & Hoogesteijn, 2008; IUCN, 2013; Tian et al., 2011). With strong predatory adaptations, the large cats are adapted to large prey, which in turn require vast habitat. O'Brien and Johnson (2005) speculate that the big Felids' need for large home ranges are a principal reason for their threatened status. Sabertooths, the prehistoric cats, filled an ecological niche as predators of large prey; this niche is now filled by the genus *Panthera* (Slater & Van Valkenburgh, 2008). A potential reason for the extinction of the large sabertooth cats was the loss of their large prey (Van Valkenburgh, 1991), another threat which today's big cats may face as human development encroaches on both their habitat and their preys'. Due to low genetic diversity among Felidae species, disease also poses a major threat (IUCN, 2013; O'Brien & Johnson, 2005). The naturalist David Quamman (2003) predicts that by 2150 large predators like the tiger will no longer exist in the wild due to human activities.

Conservation

Conservation of Felids is a complex issue and effective management strategies must take their unique predatory adaptations into consideration (Hoogesteijn & Hoogesteijn, 2008; O'Brien & Johnson, 2005; Wegge, Odden, Pokharel, & Storaas, 2009). Given big cats' reliance on large prey, particularly ungulates, effective conservation strategies

need to account for effects on both the cats and non-target species (Wegge et al., 2009). Cats help to keep the populations of their primarily herbivore prey under control, thus indirectly controlling consumption of vegetation (Estes et al., 2011). With the loss of apex predators, a trophic cascade occurs, causing the loss of diverse vegetation and eventually the animals that relied on it for food or habitat (Estes et al., 2011). Trophic cascades can have devastating and irreversible consequences for ecological communities (Estes et al., 2011). In order to prevent further widespread trophic downgrading of entire ecosystems, conservation of apex predators, such as Felids, needs to be improved.

As urban and agricultural landscapes expand alongside a rapidly growing human population, conserving more suitable land with sufficient prey for large Felids is required (Hoogesteijn & Hoogesteijn 2008; Joshi, Vaidyanathan, Mondol, Edgaonkar, & Ramakrishnan, 2013;Wegge et al., 2009). Compared to other carnivores, such as the coyote (*Canislatrans*), red fox (*Vulpesvulpes*), and raccoon (*Procyon lotor*), cats—beyond the domestic species (*Feliscatus*)—have not adapted to living in urban landscapes (Bateman & Fleming, 2012). Urban and agricultural development creates fragmented land; connections of these fragments are needed, especially for tiger conservation (Joshi et al., 2013; Tian et al., 2011). Effective conservation strategies will require long term wildlife monitoring (Datta et al., 2008).

Excellent examples of conservation strategies which take into account cats' predatory abilities are those which work with farmers to find humane ways to prevent big cats from killing livestock. One such strategy is suggested by Hoogesteijn & Hoogesteijn (2008), who identify that livestock mortality due to jaguars and pumas in Venezuela needs to be reduced, in order to increase human tolerance of the predatory cats. The suggested solution is to increase buffalo and decrease cattle farming, as buffalos will display defensive behaviour, so are less likely to be preyed on.

Datta et al. (2008) cite illegal hunting as both an indirect and direct threat to large Felids, with education and socio-economic considerations of the local people being the key to prevention. Hunting can either directly kill the big cats or indirectly affect them by removing their prey (Datta et al., 2008; Tian et al., 2011). Laws likely hold little power to prevent hunting of big cats, due to cultural traditions and the need for communities with inadequate resources to provide for themselves (Datta et al., 2008). Species such as tigers are highly valuable in illegal markets (Datta et al., 2008). Involving local communities in conservation efforts and addressing their socio-economic needs is potentially an effective way to reduce illegal hunting (Datta et al., 2008; Joshi et al., 2013).

Low genetic diversity can also hinder conservation efforts; thus, a better understanding of large cat genetics is needed (Barnett et al., 2006; O'Brien & Johnson, 2005).

Molecular genetics plays a large role in conservation of cats, due to the low genetic diversity of some species, especially tigers and cheetahs, and the valuable information it can reveal about phylogeography, systematics, coalescent dating, ecology, disease, gene mapping, and forensics (Barnett et al., 2006; O'Brien & Johnson, 2005).

The most controversial but potentially highly beneficial conservation strategy for large Felids was suggested by Donlan (2005), whereby large spaces in North America would be "re-wilded" with large vertebrate species, including large cats. The purpose of this unique conservation strategy would be to re-establish an ecosystem similar to that in the Pleistocene (Donlan, 2005). The project would be implemented with managed ecosystem manipulations and introductions of extant species which are closely related to extinct megafauna (Donlan, 2005). An early stage would introduce African cheetahs and lions, relatives of the North American cheetahs and lions (Donlan, 2005). This proposed conservation approach aims to preserve what large mammals are left and restore evolutionary and ecological potential from the Pleistocene (Donlan, 2005). However, this conservation strategy is risky due to the large financial cost and potential negative impacts to present day ecosystems, such as loss of native species (Rubenstein, Rubenstein, Sherman, & Gavin, 2006).

Conclusion

Clearly, the family Felidae and especially the genus *Panthera* are in trouble. Their already threatened populations are declining. Felids have highly conserved predatory adaptations and have shown few evolutionary changes in the last thirty million years, suggesting that their ability to adapt to current selective pressures is poor. The small cats are the youngest evolutionary Felidae species, and they may survive due to smaller habitat ranges, less human persecution, and reduced predatory conflicts with humans. Larger species, particularly *Panthera spp.* who require large ranges and present conflicts with people through their extreme predatory abilities and needs as an obligate carnivore, are at high risk of extinction. In order to ensure future survival of *Panthera spp.*, important apex predators, more consideration of their extraordinary adaptations to hypercarnivory is required.

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