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ECOLOGY OF LEOPARD (*Panthera pardus*) – CONSERVATION CHALLENGES AND THE PATH TO COEXISTENCE

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Abstract: Large carnivores such as leopards (*Panthera pardus*) are vital for maintaining ecosystem balance but are gravely threatened by habitat loss, human persecution, disease, and wildlife trade. Widespread across Africa and Asia, leopards are nonetheless poorly known and in need of urgent conservation action. Knowledge of leopard ecology is needed for effective management, especially in the Indian subcontinent, where they are the apex predator in most forest ecosystems.

Leopards are highly adaptable, inhabiting a wide variety of habitats from dense forests through arid terrain to mountainous regions up to 5000 meters. Their capacity to use a broad variety of prey species, ranging from insects to large ungulates, has made their wide distribution possible. Fossil evidence indicates their origin in Asia about two million years ago and subsequent spread to Africa and Europe. Though highly adaptable, their populations are restricted by human activities, competition from other large predators, as well as habitat disruption.

Predator-prey interactions are the building blocks of leopard populations. North American and other research indicates that large carnivores self-regulate numbers based on social behavior and availability of prey. Leopards are known to be more active at night within tiger habitats and even diurnal within tiger-free areas.

Leopard movement patterns differ considerably depending on habitat productivity and prey density. Travel distances per day vary from 3-5 km in areas of high prey density to 10-20 km in less productive habitats. Leopards travel as far as 33 km per day in areas such as the Kalahari Desert, modifying their hunting tactics according to prey availability. Opportunistic feeders, leopards prey on a diverse range of species, from rodents, antelopes, and primates to birds, and in human-dominated environments, they tend to prey on livestock, at times leading to conflict with local communities.

Competition with sympatric predators affects leopard feeding behavior. Leopards share prey with lions and hyenas in African savannas and target smaller or juvenile prey to reduce direct competition. The same pattern is noted in Indian forests, where leopards shy away from larger prey species that are favored by tigers. In Nagarhole Tiger Reserve, for example, leopards mainly prey on chital, whereas tigers target larger herbivores such as gaur and sambar.

Leopard communication is based on scent marking, vocal calls, and visual signals to maintain territories and attract mates. Scent marking by urine and feces is significant in long-distance communication and maintaining territories. Research in the Kalahari demonstrates various urination behaviors, with some being informationally oriented.

Though they are resilient, leopards are increasingly under threat from habitat loss, retaliatory killing, and illegal poaching. Habitat protection, reduction of human-wildlife conflict, and anti-

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poaching efforts must take center stage in conservation. Targeted conservation can be achieved through understanding leopard ecology, which allows researchers and conservationists to develop effective strategies to ensure their survival in the wild. The current article delineates the ecological understandings and leopard's conservation scenarios in detail.
Keywords: Coexistence, Conservation, Ecosystem, Habitat Loss, Wildlife Protection

Background

No group of organisms presents greater challenges to conservation politics and conservation biology than large carnivores. Nowadays the reduction of large predator populations is a world-wide issue. From Asia and Africa to America, the biggest of the felids, canids and ursids are subjected to several pressures of habitat loss, hunting, disease and commercial trade of body parts. Tiger (Panthera tigris), Asiatic black bear (Salenarctos thibetanus), jaguar (Panthera onca), African wild dog (Lycaon pictus) and leopard (Panthera pardus) are all at risk of extinction or local extinction. Out of a general overview of 30 large carnivore species from five families, Fuller (1995) identified that 22 of the species were listed as endangered by IUCN. However, in spite of this status, over half of these species are 'poorly studied' such as leopard. Enhancing the knowledge of leopard ecology and halting their decline are two of the most pressing conservation issues for management of leopard population in the Indian sub-continent. Irrespective of the conceptual value of ecosystem management, ecosystems are complicated, and they usually cannot be managed directly.

Ecosystems may be defined as types of vegetation or habitat, may be mapped and may be assessed based on existing area and magnitude of change from historical condition (Crumpacker et al. 1988, Scott et al. 1993, Noss et al. 1995). Yet, management of an ecosystem does demand concern with certain, measurable indicators of composition, structure, and function in that system (Franklin et al. 1981, Noss 1990, 1995). Those indicators can be tracked and up to a point controlled. The "management indicator species" term, where it is assumed that one species speaks for the whole other species grouped under the same habitat (Landres et al. 1988, Noss 1990). Tiger and leopard dominate the role in most of the Indian National Parks as the representative of the allied ecosystem. Hence, it would be well recognized that leopard as the apex predator in most of the Indian jungles requires proper attention (notably population surveys) for optimal management of particular forest and food chain. Ecological research on large carnivores in northern North America indicates they are able to regulate their own populations by social behavior (Hornocker 1969, 1970, Seidensticker et al. 1973, Beecham 1983, Hornocker and Bailey 1986), but their population is able to respond to fluctuations in prey populations (Fuller 1989, Quigley et al. 1989). In certain instances, like wolves (Canis

lupus) at high latitudes (Bergerud and Ballard 1988), predators have been found to regulate prey populations.

Where predators have been removed or significantly diminished, spectacular increases in herbivore populations are more probable than they would otherwise be with abundant carnivores (Ballard et al. 1987, Warren 1991). Conversely, prey population is also known to affect the survival rate of a predator population (Carbone and Gittleman 2002), as prey-predator relationship (availability and consumption) always takes an integral role to balance an eco-system. In most of the areas of study in conservation biology, population viability analysis, reserve design and landscape use by the carnivore are the issue of concern, which is directly connected with the trophic status of the species. It is generally presumed that a conservation plan targeting large carnivores will take care of most other species as well (Foreman 1992). Apparently, tiger and leopard being the dominant carnivores are the "umbrella species" and have a "coattail effect" (Soule 1985) for all the species that are co-occurring in the eco-system. Therefore, it is always important to know the habitat needs and the pattern of habitat utilization by the carnivore for the conservation of a landscape. Being the larger predator in Asia, the leopard has been a venerated cultural icon throughout of its former and current range. However, for over a thousand years this predator has been hunted indiscriminately for sport, killed for its parts which are supposed to possess medicinal properties, and feared and persecuted due to its undeserved fame as a ferocious killer of human and domestic animals.

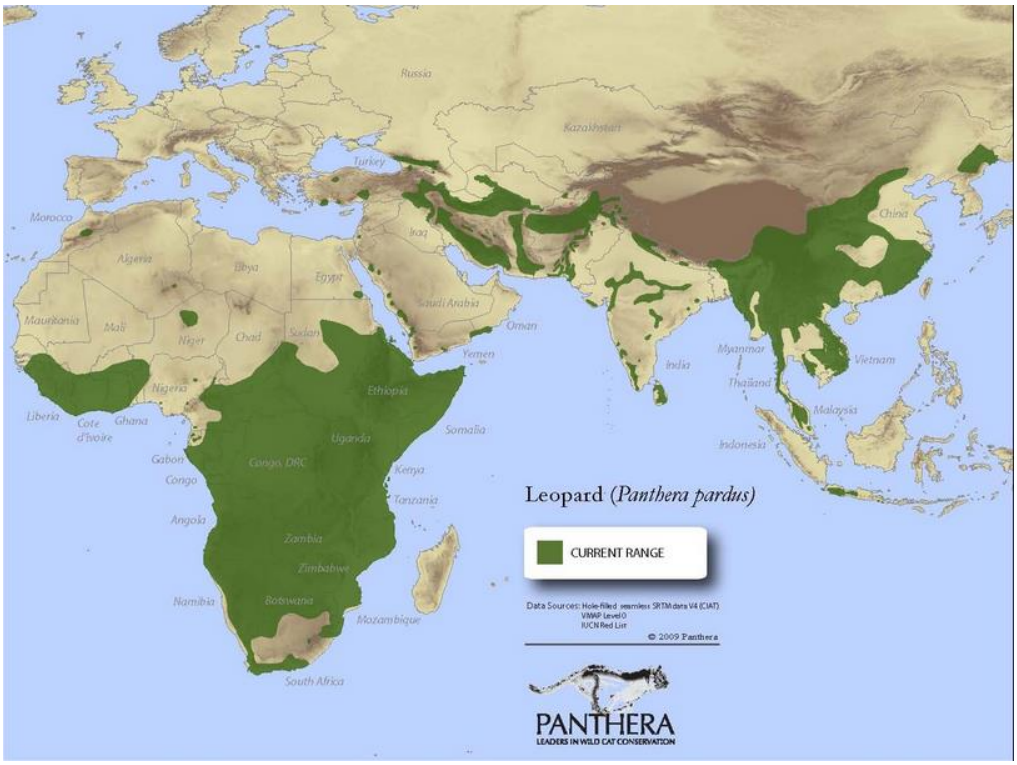
Leopard Ecology

The leopard is the most widely distributed of all felids. Its geographic range has reduced in recent history, but historically leopard was found throughout northern Africa and much of sub-Saharan Africa. Outside Africa, the leopard habitat stretched across Central Asia, India, Sri Lanka, Southeast Asia, China, Tibet and Russian Far east (Figure 1.1) (Smithers 1983, Stuart 1981, Harrison and Bates 1991, Kingdon 1977, Corbett and Hill 1992). The earliest fossil remains of the leopard have been discovered in the Siwalik Hills of the Indian subcontinent. They occur around 2 million years ago, which corresponds to the early Pleistocene. This information shows that the leopards could have emerged in Asia, most likely towards the end of the Pliocene. Nevertheless, the leopards never remained in Asia. They dispersed and settled in Africa and other areas to a large degree. Leopards were widespread across East Asia, including Southeast Asia, by mid-Pleistocene. A few moved to Northeast Asia, including Japan. Leopards entered Europe towards the middle of the Pleistocene. Their fossils have been discovered as far west as the British Isles. Leopard fossils in great numbers have been

discovered in a cave site in Italy known as Equi. Leopards became extinct in Europe and in much of Asia. They now inhabit Africa and southern parts of Asia. Their population has dwindled drastically, partly because of hunting and habitat loss (Robbins 2005).

As might be expected from its broad distribution, the leopard occurs in virtually every type of habitat (Jerdon 1867). Though absent from real deserts and beyond the tree line on mountains, leopards do occur in nearly every habitat type. It is interesting to think about which conditions could limit the distribution of this cat. Limitations in water, cover and food are generally the key determinants of an animal's distribution (Stuart 1981), but for a leopard the boundaries of these three fundamental requisites are very wide. Leopards were seen to eat many species ranging from beetles to large ungulates such as sambar and eland. Leopards even survive in isolated shrubs and trees to high density moist tropical evergreen forest (Bothma and Le Riche 1986). Desert leopards have also been reported to drink every ten days and in Russia and China they endure prolonged spells of sub-freezing weather though they seem not to be well suited for heavy snow cover (Bothma and Le Riche 1986, Miquelle et al. 1996)

Figure 1.1. Present distribution range of leopard in the World



Leopard is found in a range of forests from woodlands to Acacia savannas, scrub forest, exotic pine plantations, rocky hills and mountain terrains from sea level to elevations of 5000 m

(Harrison and Bates 1991). Leopards can live areas receiving almost no rainfall (50 mm per year) as well as in parts of West Africa and Tropical Asia where the mean annual rainfall is well over 2000 mm (Anon. 2005).

The two major factors that appear to limit the distribution of this rough and versatile generalist cat are the presence of competitors and the presence of humans. In many parts of its range the leopard co-exists with other large predators. In Africa it lives alongside lions and hyenas and in Asia it shares many habitats with tigers and wild dogs (Ramesh *et al.* 2008). Leopards do have their livelihood strategy to co-exist with these predators, similarly, they can live in proximity to humans as long as they are not persecuted and have a safe retreat (Bothma and Le Riche 1986).

Despite the leopard's widespread distribution, there is little detailed information available on this elusive cat. The work of Hamilton (1976) in Tsavo National Park, Kenya represented the first major study of leopards to incorporate radio-telemetry techniques. At the same time, Bailey (1993) initiated his study in Krugar National Park. The longest telemetry study of leopards is that of Ilany (1981) in Israel, he tracked many individuals over a 12 years period. Small scale radio-tracking studies on leopard have been conducted in conjunction with lion research in the Serengeti by Schaller (1972) and Bertrum (1982). Mizutani and Jewell (1998) studied 11 radio-tagged leopards on a ranch in Kenya. In northern Namibia, Stander *et al.* (1997) studied 18 radio-tagged leopards. Radio-tracking studies of leopard have also been part of the research on tigers in southern Nepal and Southern India (Seidensticker 1976, Sunquist 1981, Karanth and Sunquist 1995).

There is a general belief that leopards are mostly nocturnal. But, leopards are reportedly less nocturnal and more terrestrial in areas lacking tigers and lions (Grassman 1999, Eisenberg and Lockhart 1972, Karanth and Sunquist 2000). Seidensticker (1976) found that leopards living within Chitwan National Park in Southern Nepal, where tigers are also numerous, were active and moving at any time of the day and night. In contrast, those leopards living along the Park-village interface were essentially nocturnal, they were seldom found moving about during the daytime, presumably to avoid villagers (Sunquist 1981).

In the Kalahari Desert, leopards typically spend the daytime hours resting under vegetation or in burrows made by porcupines or aardvarks. Male leopards are too large to use most burrows and usually rest under bushes and trees. Kalahari leopards move mainly at night, but they frequently rest during the early part of the night and again just before dawn (Bothma and Le Riche 1986). In contrast, leopards living in the Judean desert of southern Israel rarely hunt at

night, except when occasionally hunting porcupines or house cats in human settlements. The main food items of leopards in this area are hyraxes and ibex, both of which are diurnal and so leopard in also diurnal (Ilany 1981).

In Huai Kha Khaeng Sanctuary, Thailand, a male and female leopard radio-tracked by Rabinowitz (1989) were found to be moving during the day time as at night and both were active 49-67% of the time. A similar activity pattern was recorded for leopards in Kaeng Krachen National Park, Thailand (Grassman 1999). This pattern and degree of activity is different from most of observations of leopards, although a female leopard with small cubs in Chitwan National park was active about 75% of the time (Seidensticker 1976).

The movement pattern in terms of distance traveled by leopards in their daily activities is highly variable. The walking speed of leopard is 3- 6 km per hour and they can cover up to 12-14 km in one night (Bailey 1993, Turnbull-Kemp 1967). Distances of 3 5 km per day were measured in areas with abundant prey, but in less productive habitats leopards may walk 10 to 20 km during hunting in night time (Hamilton 1976). In the interior of the Kalahari Gemsbok National Park, both males and females moved 16 to 33 km per day. It was also found that leopards in Kalahari moved increasingly longer distances per day as the number of days since they last fed increased (Hamilton 1976, Bothma and Le Riche 1990).

Leopards often catch prey opportunistically, killing vulnerable animals as they are encountered. In the Kalahari Desert, tracks revealed that leopards usually killed small prey without deliberate stalk or chase (Bothma and Le Riche 1986). In Serengeti, Bertram (1982) reported seeing leopards investigating small clumps of vegetation and pursuing any small animals flushed out. A leopards takes whatever it can catch and its diet in many areas consist largely of small to medium sized mammals (5 to 120 kg). Leopard has the ability to survive on extremely small prey, which allows them to exist in places where large prey has been exterminated. Leopards take much wider range of prey of different sized and types than most of other large cats. A number of 92 prey species were recorded in the diet of sub-Saharan leopards (Bailey 1993). In the Serengeti, a sample of 137 leopard kills included 31 different prey species (Schaller 1972). A list of mammals killed by leopards includes numerous kinds of rodents, hares, several species of deer duiker, antelope, pigs, zebras, jackals and foxes, porcupines, pangolins and monkeys. Leopard also fed on birds which include doves, partridge, guinea-fowl, peafowl, vultures, ostriches etc. Reptiles, amphibians, invertebrates and grass are also eaten by leopard. In areas where leopards live in proximity to humans, their diet often includes dogs, cats and domestic livestock including goats, sheep, calves of cow and buffalo, pigs. Instances of ‘surplus killing’

of domestic livestock sometimes occur and while large numbers of animals may be killed in this situation, few are actually eaten (Turnbull-Kemp 1967).

Where the leopard lives with lions and tigers, they feed on many of the same species, though competition may exists between them. Few studies have looked at leopard food habits in areas where they are sympatric with lions or tigers (Sankar and Johnsingh 2002, Ramesh *et al.* 2008). In presence of sympatric competitor, leopard generally feed on a wider variety of prey, many of which are small animals or the young of the larger prey species. In the Serengeti, leopards feed on Thomson's gazelles, Grant's gazelles, reedbuck and a variety of small prey species, while lions in the same area eat mainly wildbeasts, zebras, Thomson's gazelles and wild buffalo (Schallar 1972). In the Kalahari Desert, leopards take juveniles of various species including bat-eared foxes, porcupines, aardvarks, steenbok, duiker and gemsbok, whereas the main food of the lion is adult gemsbok and springbok (Bothma and Le Riche 1984). In contrast, impalas are the dominant prey of both leopards and lions in Kruger National Park, South Africa.

In Chitwan National Park, leopards feed primarily on ungulates weighing less than 50 kg, including wild pigs, hog deer and fawn or yearling of chital and sambar. Tigers in the same area tend to take prey weighing more than 50 kg which include more adult sambar, chital and wild pigs in their diet (Sunquist 1981). In Nagarhole Tiger Reserve, leopards prey extensively on chital, whereas tigers take the larger gaur and sambar (Karanth and Sunquist 1995). In Huai Kha Khaeng Wildlife Sanctuary, the major prey of both tiger and leopard is barking deer but leopards feed upon a greater diversity of small species and they take more primates than tigers do (Rabinowitz 1989).

The principal means of social integration among leopards appears to be via olfactory information carried in urine, anal sac secretions and feces. Scent may not carry information as far as a call but it is more persistent (Anon 2005), and it is not diminished by darkness as visual signs would be. Scent also has the advantage of being able to convey information long after the animal has left the spot. Auditory, tactile and visual signals are also used to attract mates or advertise that an area is occupied, but scent markings appears to be an efficient method of communication among these wide-ranging, solitary predators. Scent markings are typically deposited along commonly used travel routes, especially at road junctions or trail intersections or at conspicuous places along home range boundaries. Some marks are renew at intervals of a few days to a month or more, suggesting that these marks remain effective for relatively long periods (Smith 1977). Feces and scrapes are also left at these sites, thus providing both an olfactory and visual mark (Bothma and Le Riche 1984). Researchers in the Kalahari found that

leopards urinate in two different ways. One is copious urination that lacks any apparent informational significance, while the involves squirts of small volume deposited at regular intervals. These squirts are directed at shrubs, low branches, tree trunk or grass and are sometimes followed by raking with the hind feet (Bothma and Le Riche 1984).

The coughing, sawing or rasping vocalization of the leopard may also function to bring animals together for mating or to space out individuals, depending upon their sex and their reproductive and social status. Under favorable condition, the sawing vocalization can carry for 2 to 3 km. The leopard in making this vocalization keeps its mouth partly open and expels and inhales air back and fore across the soft palate (Brander 1923).

Leopard females can come into estrus at any time of the year and remain in heat for one or two weeks. If conception does not occur, the female may cycle again. The average length of time between estrous periods is 45 days with a variation from 20-50 days (Sadleir 1966). The onset of a heat is associated with an increase in head rubbing, rolling and vocalizing. If a male and female are not familiar with each other, aggressive encounter may occur before mating (Desai 1975). During the peak of estrous mating occurs frequently, one pair copulated 60 times during nine hour period (Desai 1975). Leopard cubs are born after a gestation period of 96 days, although zoo records suggest that gestation can take from 90 to 105 days (Hemmer 1979, Seager and Demorest 1978). Litter size of leopard commonly varies from one to three and there are records of females giving birth as many as six cubs but most litter consists of two cubs (Zuckerman 1953, Dobroruka 1968, Reuther and Doherty 1968). Female leopards use caves, thickets, hollow trees, abandoned burrows and rock piles as birth dens (Hemmer 1979).

Leopard Species

Since *Carl Linnaeus* published his description of leopards in the *10th edition of Systema Naturae* in 1758, as many as 27 leopard subspecies were subsequently described by naturalists from 1794 to 1996. The most common of all the leopard sub-species are:

- African leopard (*P. p. pardus*), (Linnaeus, 1758) — inhabits sub-Saharan Africa;
- Indian leopard (*P. p. fusca*), (Meyer, 1794) — inhabits the Indian Subcontinent;
- Javan leopard (*P. p. melas*), (Cuvier, 1809) — inhabits Java, Indonesia.
- Arabian leopard (*P. p. nimr*), (Hemprich and Ehrenberg, 1833) — inhabits the Arabian Peninsula;
- Amur leopard (*P. p. orientalis*), (Schlegel, 1857) — inhabits the Russian Far East, Korean Peninsula and Northeast China;
- North Chinese leopard (*P. p. japonensis*), (Gray, 1862) — inhabits northern China;

- Caucasian leopard (*P. p. ciscaucasica*), (Satunin, 1914), later described as
- Persian leopard (*P. p. saxicolor*), (Pocock, 1927) – inhabits central Asia: the Caucasus, Turkmenistan and northern Iran;
- Indo-Chinese leopard *(P. p. delacouri*), (Pocock, 1930) — inhabits mainland Southeast Asia;
- Sri Lankan leopard (*P. p. kotiya*), (Deraniyagala, 1956) — inhabits Sri Lanka.

A morphological analysis of characters of leopard skulls implies the validity of two more subspecies

- Anatolian leopard (*P. p. tulliana*), (Valenciennes, 1856) — inhabits Western Turkey;
- Baluchistan leopard (*P. p. sindica*), (Pocock, 1930) — inhabits Pakistan, and possibly also parts of Afghanistan and Iran.

The Indian Leopard

The Indian subspecies of leopard is *Panthera pardus fu*sca was studied. This species was first described by Friedrich Albrecht Anton Meyer in 1974, in his first description of *Felis fusca*, in which he gave account of a panther-like cat from Bengal. On the Indian subcontinent, topographical barriers to the dispersal of *Panthera pardus fusca* are the Indus River in the west and the Himalaya in the North. In the east, the lower course of the Brahmaputra and the Ganges Delta form natural barriers to the distribution of the Indo-Chinese leopard. Indian leopards are distributed all over India, Nepal, Bhutan, Bangladesh and parts of Pakistan. They inhabit in a range of forests from tropical rain forests to deciduous forests, temperate forests and coniferous forests up to an altitude of 2500 m (8200 ft) above sea level. But Indian leopard do not inhabit in the Thar desert, above tree line in Himalaya and the mangrove forests of the Sundarbans.

Panthera pardus fusca is listed as a species of near threatened by the IUCN red list. In India, this species is listed in Schedule I of the Indian Wildlife (Protection) Act, 1972, under the highest level of protection. The species faces major threats, including habitat destruction, depletion of wild prey, poaching for skins, bones, and claws, as well as the poisoning of livestock carcasses killed by leopards. As a result the geographic ranges of leopard have contracted and their populations have declined. There is an urgent need to conserve many carnivore species including leopard and the first step towards this is to obtain knowledge about their basic biology: how many exist, what they eat and where they live.

Conclusion

Leopards, being top predators, are responsible for maintaining ecological balance through regulating prey populations and trophic dynamics. Their ability to survive in varied habitats—

ranging from dense forests to deserts—testifies to their resilience, but their survival is threatened more and more by habitat loss, human-leopard conflict, and poaching. Conservation efforts must thus include habitat conservation, mitigation of human-leopard conflict, and enhancing legal measures to ensure their long-term survival.

Long-term conservation measures, such as the establishment of protected areas, wildlife corridors, and community participation, are critical to leopard population maintenance. Scientific monitoring through the application of cutting-edge technologies like camera traps and genetic analysis can provide data on their population trends and habits, which can inform focused conservation measures. Policies also need to be attuned to local socio-economic conditions to promote coexistence between humans and leopards through sustainable land-use planning and education programs.

Future conservation efforts should also focus on addressing climate change effects, which compromise leopard habitats through changes in prey distribution and environmental conditions. Government, conservation bodies, and local communities working together can maximize the success of conservation efforts to ensure that leopards remain viable in the wild. In the end, the survival of leopards depends on humanity's dedication to biodiversity conservation. Conserving them is not only about conserving one particular species but keeping ecosystems intact where countless other species, including mankind, find homes. Through holistic thinking that provides an equilibrium of ecological and human demands, it is possible for us to save these incredible hunters and the lavish habitats they make their own. The challenge is not just in scientific and policy-led interventions, but in promoting a shared consciousness and appreciation for our planet's natural heritage as something to be cherished and preserved for future generations.

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