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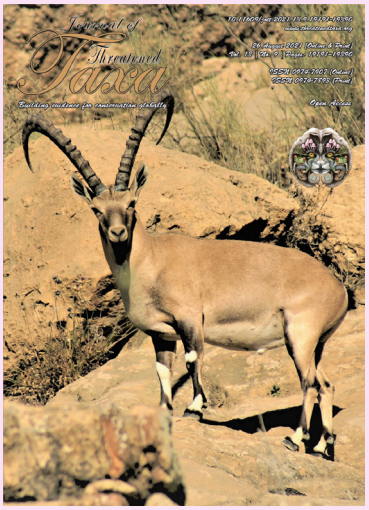

COMMUNICATION

DIET OF LEOPARDS *PANTHERA PARDUS FUSCA* INHABITING PROTECTED AREAS AND HUMAN-DOMINATED LANDSCAPES IN GOA, INDIA

Bipin S. Phal Desai, Avelyno D'Costa, M.K. Praveen Kumar & S.K. Shyama

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COMMUNICATION

Diet of Leopards *Panthera pardus fusca* inhabiting protected areas and human-dominated landscapes in Goa, India

Bipin S. Phal Desai [1], Avelyno D'Costa [2], M.K. Praveen Kumar [3] & S.K. Shyama [4]

[1–4] Department of Zoology, Goa University, Taleigao Plateau, Goa 403206, India.
[1] Goa Forest Department, Government of Goa, Goa 403001, India.
[1] phaldesaibipin00@gmail.com, [2] avelynodc@gmail.com, [3] here.praveen@gmail.com, [4] skshyama@gmail.com (corresponding author)

Abstract: The diet of leopards occupying human-dominated and protected areas (PAs) in Goa, India was analyzed through scat analysis. A total of 117 scats, 55 from wildlife sanctuaries/ national parks and 62 from human-dominated areas were collected and analyzed. Analysis of 55 scats from protected forests revealed the presence of only wild prey in the leopard diet, whereas 61% of scats collected from human-dominated areas consisted of only wild prey, 29% of domesticated animals, and 10% a mixture of both wild prey & domesticated animals. Of the prey biomass consumed in human-dominated areas, domestic animals constituted only 33% of the leopard diet. Among all leopard scats, 71% contained only one prey species, 28% contained two species, and 1% contained three.

Keywords: Diet composition, hair medullary pattern analysis, human-leopard interactions, scat analysis.

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Author details: Mr. Bipin S. Phal Desai is a Range Forest Officer of the Goa Forest Department, Government of Goa. His research interests include wild cat biology and man-wildlife conflict studies. Dr. Avelyno H. D'Costa is an Assistant Professor in the Department of Zoology, Goa University. He is an ecotoxicologist and is interested in research related to genetics, ecology and conservation. Dr. M.K. Praveen Kumar is is a toxicologist and is interested in research related to genetics and biotechnology. Dr. S.K. Shyama is a Professor (Rtd.) and ex. head of the Department of Zoology, Goa University. His area of expertise is genotoxicology and interests include ecotoxicology and wildlife biology. He has guided several PhD students in toxicology and wildlife and conservation.

Author contributions: BSPD collected the samples, analyzed them and wrote the manuscript. AD'C assisted with the analysis of the samples and revision of the manuscript. MKPK assisted with the analysis of the specimens. SKS supervised the study and helped in the revision of the manuscript.

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INTRODUCTION

Big cats play an important role in maintaining the equilibrium of forest ecosystems, for which they serve as indicators of health and integrity. Tigers *Panthera tigris* and Leopards *Panthera pardus* are integral parts of forest ecosystems (Karanth & Sunquist 1995) and hence their conservation is of prime importance. Leopards are widely distributed in India and they often come into conflict with humans, indeed they are more frequently involved in human conflict than other large cats (Holland et al. 2018). Many examples have been reported from Sanjay Gandhi National Park (Mumbai), Baria Forest Division (Gujarat), Junnar (Maharashtra), and Garhwal (Himalaya), and conflicts are becoming increasingly prominent with an increasing human population and expanding developments leading to competition for shrinking resources. This presents major obstacles to the conservation of leopards, and a comprehensive region-specific study of their ecology and biology is essential for long-term conservation.

Several studies have documented the widespread distribution of leopards across India (Daniel 1996; Vijayan & Pati 2002; Athreya et al. 2013), but few studies have focused on prey availability and diet composition in human-dominated areas (Athreya et al. 2013, 2014). Hence in this study, an effort has been made to compare the diet of leopards in human habitations with those living in PAs in Goa, India using scat analysis. Scat analysis is an indirect, non-destructive and cost-effective method (Sunquist 1981; Johnsingh 1983) for recording the frequency of occurrence of prey items in the diet of a carnivore. The hair of prey is relatively undamaged in scat of leopards and tigers, hence it can be used as a tool to identify prey species (Mukherjee et al. 1994a; Ramakrishnan et al. 1999). However, there is a chance of error if molecular methods are not used to confirm species identity (Laguardia et al. 2015; Akrim et al. 2018).

In Goa, the Western Ghats run along the eastern border of the state which contains protected forest areas. In addition to this, there are various small hill ranges and plateaus stretching from Pernem in the north to Canacona in the south that connect the Western Ghats with the coastal landscape. Most of the old human settlements are situated at the base of these hills and plateaus. In the last decade or so, these areas have become prone to encroachment due to expansion of cities, towns, villages and roads. These hills and plateaus primarily consist of stunted cashew trees, thorn scrub jungle and coarse grass with dense semi-evergreen forest patches in between (Jadhav & Pati 2012), which support a variety of wildlife, such as the Indian Leopard *Panthera pardus fusca,* Golden Jackal *Canis aurius,* Dhole *Cuon alpinus,* Gaur *Bos gaurus,* Sambar *Rusa unicolor,* Chital *Axis axis,* Northern Red Muntjac *Muntiacus vaginalis,* Wild Boar *Sus scrofa,* Indian Chevrotain *Moschiola indica,* Bonnet Macaque *Macaca radiata,* Gray Langur *Semnopithecus hypoleucos*, and Indian Crested Porcupine *Hystrix indica*.

In this work we have studied the diet composition of leopards in PAs as well as human-dominated areas in Goa over a period of three years by collection and analysis of scats, to identify potential human conflicts due to livestock depredation, and to formulate management interventions and mitigating measures.

Study area

Goa is spread over the hilly region of Western Ghats towards the east, coastal plains towards the west, a midland region with laterite plateaus and low-lying river basins. The study area consisted of the entire state of Goa lying in between latitudes 15.480–14.435N and 74.201–73.403E which included human-dominated areas, with reported presence of leopards and wildlife sanctuaries and national parks covering a total area of ~1,748.05 km^2 (Figure 1). The average altitude of Goa is approximately 511 m. The total geographical area is 3,702 km^2 of which 2,219 km^2 is covered with forests and 1,224 km^2 represents state-owned forests, of which 649 km^2 have been declared protected areas in the form of a national parks and wildlife sanctuaries. The overall human population density in Goa is 394 persons per km^2. Goa receives an average annual rainfall of 3,300 mm, and the major forest types are tropical wet evergreen, tropical semi-evergreen, tropical moist deciduous, and littoral & swamp forests.

MATERIALS AND METHODS

Field collection of leopard scats

Leopards and tigers prefer use of forest road and footpaths/trails to move around and also as a mechanism of inter and intra species social communication, hence they are likely to defecate along such paths (Smith et al. 1989; Karanth et al. 2004). Scat samples measuring larger than 20 mm in diameter (measured using a custom-made 20 mm diameter metal ring) were collected to avoid non-leopard predator scats (Norton et al. 1986; Rabinowitz 1989). The presence of tigers was only reported from Mhadei Wildlife Sanctuary (WS), where leopard scats were differentiated from tiger scats based on size, shape, diameter, coiling and constriction patterns, along with

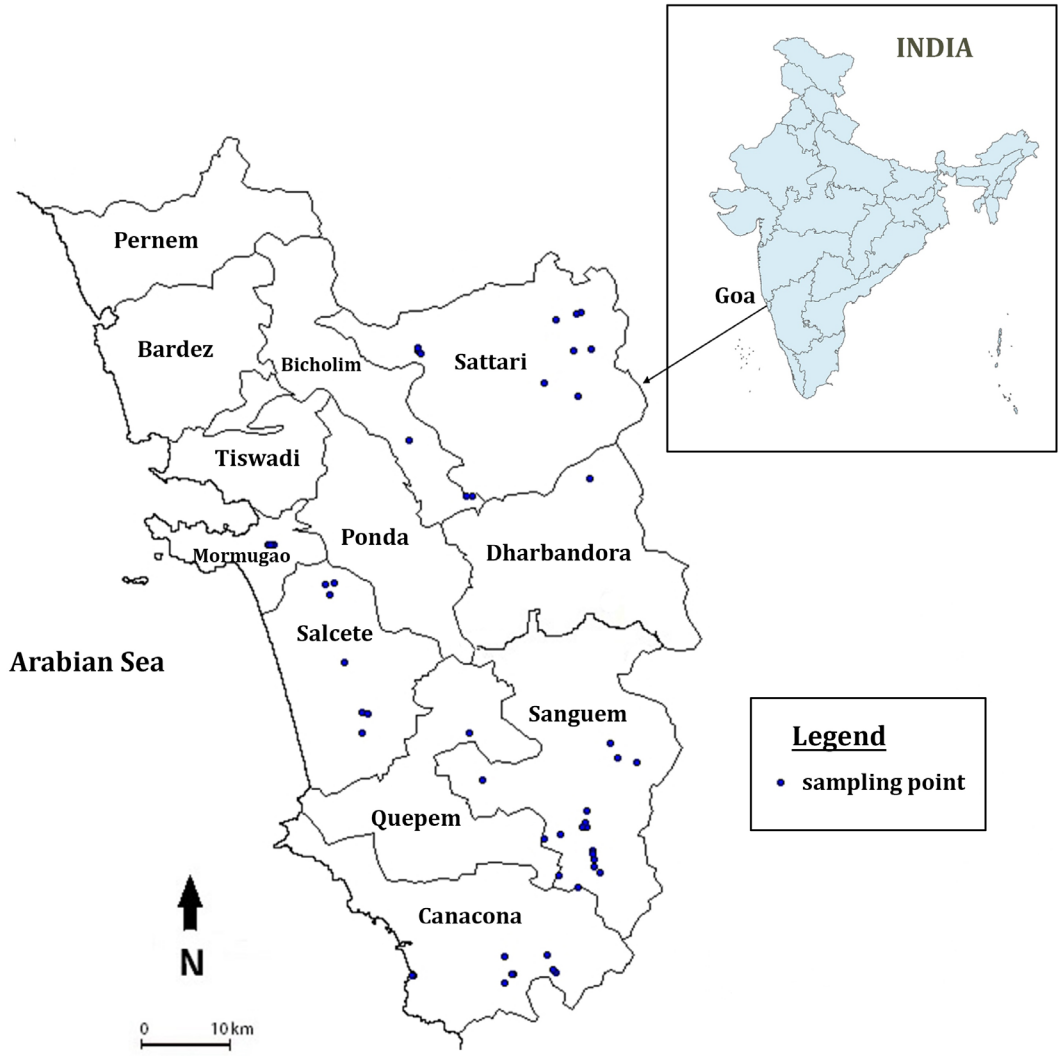

Figure 1. Map of Goa showing scat sampling points.

ancillary evidence such as pugmarks, scrapes, and claw marks (Lovari et al. 2014; Laguardia et al. 2015; Rostro-Garcia et al. 2018). It is important to note that there is a chance of identification error since molecular techniques were not used.

Scat collection from protected forest areas

A preliminary scat survey was conducted to identify carnivore trails such as foot paths and forest roads passing through the protected forest areas (wildlife sanctuaries and a national park). A total of 25.5 km of forest roads were sampled once every month with trained personnel.

Scat collection from human-dominated areas

To identify areas with potential human-leopard conflicts, complaint and rescue data was collected from the Forest department of Goa for the years 2013–2016. Using this data, areas prone to human-leopard interactions were identified. These areas were later visited to study the geography, crop patterns and proximity with dense forest areas of protected areas.

Preliminary scat survey was conducted to identify carnivore trails such as foot paths and unmetalled roads passing through areas having forested areas close to human habitation (hamlets with small houses and fields) with maximum complaints on leopards. These areas have medium to dense green cover and provide shelter to leopards and wild prey species. Sampling at each site was carried out once a month. A total of 34 km from such areas were sampled over a period of three years from January 2016 to December 2018.

Scats were measured and collected in polythene bags labeled with the date of collection along with the GPS location of the site. Scat samples were transported

to the lab, sun dried and the dry weight recorded. A portion of dried scats were soaked in water and passed through a metal sieve (1.5mm mesh size), leaving only undigested prey remains which predominantly consisted of hair and bone fragments. Hairs from the undigested remains were then separated and 25 hair strands were randomly picked from each sample and analyzed. For hair medullary pattern analysis, hairs were immersed in xylene for 24 hours and then mounted on permanent slides with a cover slip using DPX mount (Mukherjee et al. 1994b). For observing cuticle scale patterns of hair, an impression technique using gelatin solution with eosin stain was used following Mukherjee et al. (1994b). Slides were examined under 200x and 400x magnification based on the size of the hair using a trinocular research microscope (Olympus BX53). A set of reference slides were made from domesticated livestock and pet animals from the study area and wild prey species in captivity, rescued animals and road kills.

Prey species (identified from hair found in scat) were reported as the proportion of scats that showed their presence. A species accumulation curve was also plotted (Kshettry et al. 2018) to ascertain the number of scats required to be analyzed for a reliable diet estimate. To avoid bias due to variable prey body size, relative composition of prey species varying in body size was calculated using Ackerman's equation (Ackerman et al. 1984), assuming leopards have similar digestive physiology to Mountain Lions *Puma concolor* (Karanth & Sunquist 1995), as follows:

$Y= 1.980+0.035x$

Where Y is the kg of prey consumed per field collectible scat, and X is the average weight of the particular prey species in kg (Ackerman et al. 1984). This method has been used previously for leopards (Karanth & Sunquist 1995; Andheria et al. 2007; Khorozyan et al. 2008; Odden & Wegge 2009; Mondal et al. 2012; Athreya et al. 2014). The body weights of probable predated prey species were taken from literature (Mondal et al. 2012; Athreya et al. 2014).

The relative biomass (D) and relative numbers (E) of each prey species consumed was obtained using the equations:

$D= (A \times Y)/ \sum(A \times Y) \times 100$

$E= (D/X)/ \sum(D/X) \times 100$

Where A is the frequency of occurrence of the prey items in the scats, Y is the mass of prey consumed per scat (kg) and X is the mean mass of the prey (kg) (Athreya et al. 2014).

RESULTS

Protected areas

Analysis of scats collected from PAs revealed the presence of only wild prey (Indian Crested Porcupine, Wild Boar, Northern Red Muntjac, Chital, Indian Hare *Lepus nigricollis*, Bonnet Macaque, and Gray Langur) in the diet of leopards. No records of domesticated animals (such as ox, dog, pig, goat, and cat) were found in the scats from protected forest areas. Scat analysis of 55 scats collected from these areas (Table 1) revealed that Wild Boar constituted a major proportion of the prey biomass (29%), followed by Chital (25%), Indian Crested Porcupine (15%), Barking Deer (13%), Gray Langur (5.6%), Bonnet Macaque (5.4%), Sambar (4.1%), and Indian Hare (3.1%). Indian Hare was the most preyed-upon species in relative numbers (21%) followed by the Indian Crested Porcupine (18%), Bonnet Macaque (15%), Wild Boar (13%), Gray Langur (12%), Northern Red Muntjac (11%), Chital (8.9%), and Sambar (1.1%). The diet profile analysis also suggests that leopards preferred small-sized prey (77%), over medium (33%), and large-sized prey (1.1%) (Table 1).

Human-dominated areas

The results of analysis of 62 scats collected from human-dominated areas revealed that major proportion of leopard prey biomass comprised of wild prey (67%), predominantly Wild Boar (26%), Indian Crested Porcupine (17%), Indian Hare (14%), Bonnet Macaque (5.1%), Gray Langur (3.2%), and Northern Red Muntjac (1.3%). Domestic animals (dog, pig, cat, and goat) constituted only a minor portion (33%) of the leopard diet. The dog was the most preyed-upon domestic animal (17%) followed by pig (11%), goat (2.7%), and cat (2%) (Table 2). Of the nine wild prey species observed from scat analysis, six were identified in scats collected from human-dominated areas.

Comparative analysis of leopard habitats

A total of 117 leopard scats were collected during the period of the study, of which 55 were from PAs and 62 from human-dominated areas; 62% of scats collected from human-dominated areas contained only wild prey, 29% only domestic prey, and 9.7% had a mixture of both. A majority of scats (71%) contained only one prey species, 28% contained two species and 0.85% contained three (Figure 2). A total of 151 prey items were identified, comprising of 12 prey species.

In both habitats, Indian Hare remains were observed in the most scats (42%), followed by Indian Crested Porcupine (13%) and Wild Boar (8.7%). Of the total prey

Table 1. Diet composition of Leopards inhabiting protected forest areas in Goa through analysis of scat samples (55) during January 2016 to December 2018.

	Prey species	N (Percent occurrence)	Average body weight (X)	A (%) (Percent frequency)	Y (Kg/scat)	D (%) (Relative biomass)	E (%) (Relative number of individuals consumed)
1	Indian Crested Porcupine	12	14	17.39	2.47	14.57	17.69
2	Wild Boar	18	37	26.08	3.27	28.98	13.31
3	Northern Red Muntjac	10	20	14.49	2.68	13.18	11.19
4	Gray Langur	5	8	7.25	2.26	5.56	11.80
5	Indian Hare	3	2.5	4.35	2.07	3.05	20.73
6	Bonnet Macaque	5	6	7.25	2.19	5.38	15.25
7	Dog	0	18	0	2.61	0	0
8	Chital	14	48	20.29	3.66	25.19	8.92
9	Pig	0	30	0	3.03	0	0
10	Sambar	2	62	2.90	4.15	4.08	1.12
11	Cat	0	3.5	0	2.10	0	0
12	Goat	0	25	0	2.85	0	0
	Total	69					

Y—estimated weight of the prey consumed per collectable scat produced.

Table 2. Diet composition of Leopards inhabiting human-dominated areas in Goa through analysis of scat samples (62) during January 2016 to December 2018

	Prey species	Percent occurrence (N)	Average body weight (X)	A (%) (Percent frequency)	Y (Kg/scat)	D (%) (Relative biomass)	E (%) (Relative number of individuals consumed)
1	Indian Crested Porcupine	15	14	18.29	2.47	17.24	11.20
2	Wild Boar	17	37	20.73	3.27	25.91	6.37
3	Northern Red Muntjac	1	20	1.22	2.68	1.25	0.57
4	Gray Langur	3	8	3.66	2.26	3.15	3.59
5	Indian Hare	15	2.5	18.29	2.07	14.43	52.49
6	Bonnet Macaque	5	6	6.10	2.19	5.10	7.72
7	Dog	14	18	17.07	2.61	17.01	8.59
8	Chital	0	48	0	3.66	0	0
9	Pig	8	30	9.76	3.03	11.28	3.42
10	Sambar	0	62	0	4.15	0	0
11	Cat	2	3.5	2.44	2.10	1.96	5.08
11	Goat	2	25	2.44	2.85	2.66	0.97
	Total	82					

Y—estimated weight of the prey consumed per collectable scat produced.

biomass consumed, domesticated animals constituted a minor fraction (17%) of the leopard diet, the remainder consisted of Wild Boar (27%), Indian Crested Porcupine (16%), Chital (12%), Indian Hare (8.9%), Northern Red Muntjac (7.1 %), Bonnet Macaque (5.2%), Gray Langur (4.3%), and Sambar (2%).

The cumulative curve (Figure 3) suggested that the proportion of scats with remains of various prey species stabilized after 24 scats, with only one species being added after 71 scats. From this analysis it can be also interpreted that 92% of prey species were identified in the first 24 scats analyzed, with an addition of just one species

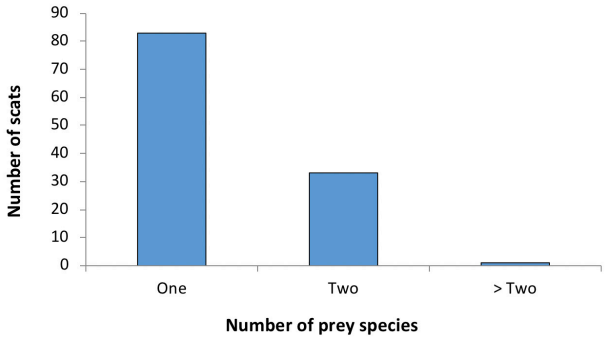

Figure 2. Number of prey species observed in each Leopard scat.

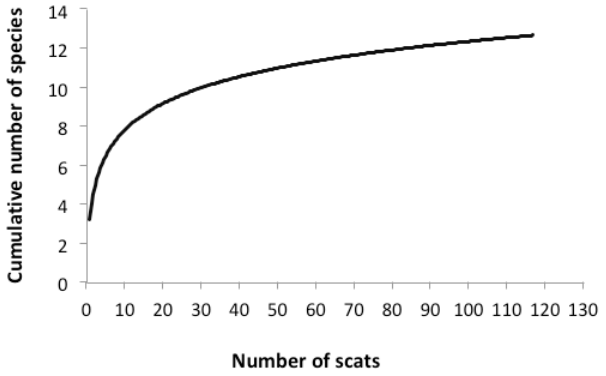

Figure 3. Cumulative number of prey species in Leopard scats.

(cat) after analysis of the 71st scat. Thus we consider the sample size adequate to interpret the overall diet profile of leopards from the study area.

DISCUSSION

The presence of eight wild prey species in the study area may be attributed to the availability of diverse vegetation from dry thorn forests to semi-evergreen forests. The presence of leopards in human habitations is evident from the data collected from the forest department regarding complaints received from a majority of the human-dominated areas of North Goa and South Goa districts. Hence it is likely that Leopards may be distributed throughout the state of Goa.

Data analysis from protected forest areas suggests that leopards consumed medium- (Wild Boar, Northern Red Muntjac, Chital) and small-sized prey (Indian Hare, Indian Crested Porcupine, Bonnet Macaque, Gray Langur). The Indian Hare was found in the most scats, followed by Indian Crested Porcupine, Wild Boar, Gray Langur, Bonnet Macaque, Northern Red Muntjac, Chital, and Sambar. The preference of smaller to medium-sized prey was also reported in the studies of Sunquist & Sunquist (1989), Sankar & Johnsingh (2002), Henschel et al. (2005), and Ahmed & Khan (2008). Additionally, this preference may also be due to the nocturnal feeding behaviour of Leopards as well as these small mammals, thus making them more vulnerable to predation than the other species (Ahmed & Khan 2008). Another point to be considered is that in the study area, wild prey were also found to be present in human-dominated areas for the purpose of grazing or foraging which could also be a reason for the leopards entering these areas.

With regard to the domestic animals, the predation of dogs and pigs was mostly due to an increase in stray dog and pig population in human habitation probably due to improper disposal of garbage in these areas. Very few households had a safe night shelter for their domesticated pigs and dogs. During the study although few complaints of leopard attacks on cattle calves were reported, no such killings were found. Further no traces of cattle hair were found in any of the scat samples.

From informal observations and discussions with locals we realized that though leopards came into conflict with humans almost throughout the year, this conflict is significantly higher during the months of August, September, and October and again intensifies in the months of January and February. This pattern correlates with the breeding pattern of leopards (pre-breeding phase during the monsoon months of August, September, and October) when wandering males and sub-adult cubs (which have just left their mothers to fend for themselves) come in conflict with humans. The conflict during the January and February months could be mainly due to the movement of females in the post-birth phase. These leopards, which continuously change their location for the safety of the young cubs, come in contact with humans employed in cashew plantations and other agricultural activities.

CONCLUSION

It can be interpreted from our data that although leopards were reported close to human habitations throughout the year, their dependence on domestic animals was low. This study also indicates that the wild species that the leopards preyed upon in PAs were also present in forested areas close to human habitations. This could be the reason for the presence of leopards in human-dominated areas with a low dependence on domestic animals. Hence it is of utmost importance to create awareness about the role of these large cats in

ecosystems and their feeding and behavioral patterns, and to adopt mitigating and precautionary methods in case of human-leopard conflicts.

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