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Conservation Priorities for the Peruvian Yellow-Tailed Woolly Monkey (*Oreonax flavicauda*): A GIS Risk Assessment and Gap Analysis

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Abstract: An inductive GIS (Geographical Information System) process was used to create a realistic Habitat Suitability Model (HSM) for the current distributional range of the Peruvian yellow-tailed woolly monkey (*Oreonax flavicauda*) to aid current conservation initiatives and to help set future conservation priorities for the species. In combination with this, we produced an ecological risk assessment model of the study region to assist in site selection for priority areas for conservation actions, which included the expansion of the existing protected area system and the creation of new reserves in areas forming natural biological corridors in the northeastern Peruvian departments of Amazonas and San Martín. This study incorporates information regarding the threat of hunting and other anthropogenic pressures on the species into the site selection process. *Oreonax flavicauda*, currently on the *IUCN Red List of Threatened Species* as Critically Endangered, was once thought to be extinct. Since its rediscovery in 1974, however, there has been little research on this species due to its small population size, restricted distribution, and the difficulty of access to its mountainous habitat. A gap analysis showed that the current protected area network was inadequate to conserve the yellow-tailed woolly monkey's current suitable habitat. This finding underlines the urgency of upgrading the protected area network as well as implementing other conservation initiatives. The selection of sites suitable for the creation of new protected areas was based on habitat composition, altitudinal and geographical limits, and proximity to human influences, using an inductive process of extracting information from locations where *O. flavicauda* is known to occur, from existing demographic information on human populations, and by qualitative judgments. We recommend urgent action to protect this species before population numbers decrease further.
Key Words: Yellow-tailed woolly monkey, *Oreonax flavicauda*, deforestation, arcGIS, cloud forest, tropical Andes

Introduction

The yellow-tailed woolly monkey (*Oreonax flavicauda*) is endemic to the Peruvian Andes, and the largest of Peru's primates (Leo Luna 1987). It is also one of the most threatened; listed as Endangered on Appendix I of CITES (2005) and as Critically Endangered on the *IUCN Red List of Threatened Species* (Cornejo *et al*. 2008). It has also been on the list of the World's 25 Most Endangered Primates since 2006 (DeLuycker and Heymann 2007; Cornejo *et al*. 2009). Even so, comparatively little investigation or conservation work has been carried out on this species and very little is known about its status. There are no accurate population estimates, but Nowak (1999) wrote that there were only 250 individuals surviving in the wild. Although this is probably an underestimate, the current population will not be much larger than this, and is surely decreasing, making more effective conservation measures critical to the species' survival.

Oreonax flavicauda, a flagship species for the Tropical Andes Biodiversity Hotspot (Myers *et al*. 2000) has a very limited geographical range (Leo Luna 1987; Shanee *et al*. 2007, 2008). It can be found only in a small area of primary montane and cloud forest in the Peruvian departments of Amazonas and San Martín (Butchart *et al*. 1995) between the altitudes of 1,500 m and 2,700 m above sea level (Leo Luna 1982; DeLuycker 2007). Early locality records have also shown the occurrence of this species in small areas of the neighboring departments of Huanuco, Loreto, La Libertad and Cajamarca (Mittermeier *et al.* 1975; Graves and O'Neil 1980; Leo Luna 1980, 1982, 1989; Parker and Barkley 1981; DeLuycker 2007).

The threats that determined the status of *O. flavicauda* as Critically Endangered include hunting and deforestation.

Despite being prohibited under Peruvian law, subsistence and trophy hunting still occur throughout the species' range. Hunting is made easier by its conspicuous nature and large size. At least 20 monkeys were hunted in the areas surrounding the Bosque de Protección de Alto Mayo and the Zona Reservada Cordillera de Colán over 18 months in 2007–2008 (Shanee *et al.* in prep.). The rate of deforestation in Amazonas and San Martín is among the highest in Peru (Peru, INEI 2008), fuelled by the need for agricultural land, coffee cultivation and small- and large-scale timber extraction (DeLuycker 2007; Shanee *et al*. 2007; EDGE 2008). The widespread deforestation that has occurred in this region has, in many areas, forced *O. flavicauda* into isolated forest fragments (Shanee *et al*. 2007). Although the area currently occupied by *O. flavicauda* is unknown, in 1981, Leo Luna (1982) estimated its potential forested habitat to be at least 11,240 km², but predicted that this would decrease by 1,600 km² by 1991. Based on these figures and projected rates of deforestation, DeLuycker and Heymann (2007) estimated that by 2006 potential forested habitat would have been reduced to 7,240 km². These (conservative) estimates represent a loss of approximately 35% of the total potential habitat for this species in just over two decades.

Until the 1950's this species was well protected due to the inaccessibility of its habitat, characterized by high mountain ridges and steep river valleys. Since then, however, new roads have been built throughout its range. The roads have brought with them immigrants from the Peruvian coast and the high mountain sierras, and have resulted in increased deforestation and the fragmentation of much of its habitat. Woolly monkeys have very low reproductive rates, with long interbirth intervals, and population densities are always low. These factors contribute to its vulnerability to anthropogenic pressures (Leo Luna 1987).

Here we create the first realistic Habitat Suitability Model (HSM) for the yellow-tailed woolly monkey, using inductive GIS modeling methodology to predict its current geographic distribution in Amazonas and San Martín. We also carried out a GAP analysis of the current protected area (PA) network in the region to assess the extent to which its habitat is protected, to determine zones of potential threat, and to predict which areas would be optimum for the creation of new protected areas and corridors to bridge priority areas.

Methods

There is limited information on the habitat preferences and current distribution of *O. flavicauda.* It is known to occur throughout the departments of Amazonas and San Martín on the eastern slopes of the Andean Cordillera in northeastern Peru between 3° and 9° south and 75° and 79° west. These departments border Ecuador to the north, and the departments of Loreto, Huanuco, La Libertad and Cajamarca (to the east, south, southwest and west, respectively). The topography of the departments of Amazonas and San Martín range from high mountain sierras to lowland rainforest. Combined these departments have a human population of close to a million (Peru, INEI 2008). There are a number of protected areas, including the Zona Reservada Cordillera de Colán in Amazonas and the Parque Nacional Río Abiseo and Bosque de Protección de Alto Mayo in San Martín. Yellow-tailed woolly monkeys inhabit forests at altitudes of 1,500–2,700 m above sea level. Their range is limited in the north by the Río Marañon valley and to the northwest by the Río Utcubamba valley.

Data collection

Data collected for this study included field observations, ecological niche data, land use maps, and digital maps including the Digital Elevation Model (DEM) of Peru (<http://www.srtm.usgs.gov>). We searched the literature, printed and online material, to include all sightings and distribution data for the species. We included sightings resulting from our ongoing surveys in Peru (S. Shanee pers. obs.; Hans Dignum pers. comm.), and where possible we contacted people involved in previous research in order to record any additional unpublished localities. We checked online museum collections but the only extra record we found was discounted because the location given was too vague.

We used ArcView 9.2 (ESRI 2008) for analysis and modeling. Land use maps were obtained from the Instituto de Investigaciones de la Amazonía Peruana (IIAP) (Peru, IIAP 2007, 2008) and additional reserve data from Amazonicos Para la Amazonia (Miraliz Egoavil pers. comm.). To make data sets more manageable, land-use files were reclassified to nine land cover classes, as follows: Palm Forest, Scrub, Marsh, Deforested areas, Forest, Fig (*Ficus* spp.) dominated forest, Population Centers, Mixed Areas, and waterbodies). The forest class was then subdivided into a further six classes as follows: Mixed communities, Andean forests in high mountains with medium trees associated with thickets, Andean forests with medium and large trees in high mountains, Sub-Andean oriental, Lower montane forest with medium trees, and Sub-Andean of steep mountains with large trees. DEM90 from the Shuttle Radar Topography Mission in raster format was also reclassified to a set of 12 altitudinal classes from 0 to >3,000 m above sea level.

Distribution and Habitat Suitability Modeling (HSM)

Locality data collected were converted into decimal degrees and assigned the WGS84 coordinate system. Using similar methods to Ramp *et al*. (2005), a kernel density transformation was applied to *O. flavicauda* point locality data. In some cases several localities were aggregated to a single point to avoid over representation due to more detailed field work at any given point. A total of 43 localities were used to create 27 points (Fig. 1). This was used to determine species "hotspots", where there were the highest densities of *O. flavicauda* sightings.

The final HSM was created using three methods; Environmental Envelope Modeling, Inductive Decision-tree Methods, and Habitat Suitability Preference Indices. Habitat preference indices were created for each of the separate land cover, forest, and altitudinal classes found within the predicted distribution of *O. flavicauda* following a similar method used by Aspinall (1993). Each of the variables in these three were weighted and allocated a Marginal, Good or Very Good habitat class. Once suitability classes had been assigned to the seven land cover classes and 12 altitudinal categories, Boolean maps were created for each of the different classes (19 in total).

Ideally, habitat models require field validation, but in this case validation techniques were limited to statistical sign and literature validation. Chi-square tests were used to test forest and altitudinal preferences shown by actual localities against equal numbers of random points. A final test was made by overlaying the HSM against known deforested and urban areas.

GAP analysis and ecological risk assessment

ArcGIS 9.2 (ESRI 2008) was used to produce a Gap analysis of the current protected area network within the study region to examine how much of the species habitat is currently protected and to show gaps in the existing network. Datasets used to complete the gap analysis included the following: weighted HSM, protected area network data layer, urban area data layer, road network dataset, and populated areas data layer. Overlaying the protected area (PA) network dataset (Peru, IIAP 2007, 2008) on top of the weighted HSM highlighted areas that needed attention. Approximate area values were calculated by multiplying the area of each raster cell by the total number of cells for each suitability category (i.e., Marginal, Good, Very Good). This was used to find out the area of each suitability class that fell within each of the existing PAs to estimate efficiency at protecting the species current habitat based upon the weighted HSM.

A risk analysis was carried out to assess areas of *O. flavicauda* habitat facing the highest threats due to proximity to human development (Peyton *et al*. 1998). Urban and populated areas and road network data were used to assess threat levels. Each area outside a PA was classified to one of four threat levels based on proximity away from human development (>8 km No Risk, >4 km and <8 km Low Risk, >0.5 km and <4 km Medium Risk, <0.5 km High Risk). The new risk layers, together with the weighted HSM layer, were then converted to vector layers and given unique fields depending on degree of threat. Non-suitable habitat was then removed from the layer and a new layer created to show only areas of suitable habitat at all levels. This was then used to create a layer showing only areas of No or Low Risk, the PA network was then overlaid on top of the risk assessment layer to highlight gaps in the network and priority areas of high suitability for the creation of new reserves and corridors. These areas were those that showed No or Low Risk combined with Good or Very Good habitat.

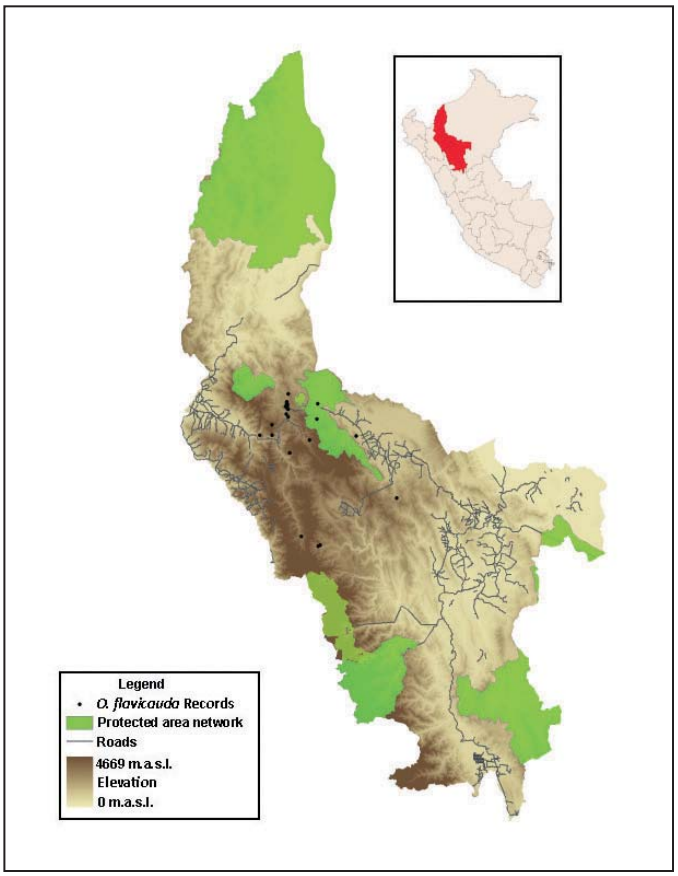

Figure 1. *Oreonax flavicauda* locality records used in this study.

Results

Habitat Suitability Modeling (HSM)

Habitat preference from suitability indices calculated based on field observations and literature searches determined that forested (excluding palm dominated forest) areas from 1,600 to 1,800 m above sea level, and 2,200 to 2,400 m above sea level constituted "Good habitat", and forested areas between 1,800 and 2,200 m above sea level constituted "Very Good habitat". Based on this model there is a total of 6,302 km² of habitat available to *O. flavicauda*, of this only 2,024 km² is rated "Very Good". The majority of remaining habitat is found in the northern area of the species' range and along the southwestern border of the Department of San Martín.

Table 1. Suitable habitat within the protected area (PA) network and outside the PA network.

Habitat suitability	Total Area (km²)	Within PA network (km²)	Within PA network (%)	Outside PA network (km²)	Outside PA network (%)
Good	4278	1128	26	3150	74
Very Good	2024	739	37	1285	63
Total	**6302**	**1867**	**30**	**4435**	**70**

Gap analysis

Only 30% of remaining suitable habitat in Amazonas and San Martín is found within the PA network, leaving 70% unprotected. Thirty-seven percent of remaining habitat rated as "Very Good" is found within the PA network, leaving 63% unprotected (Table 1).

Gap analysis of existing protected areas within the species' range showed the largest areas of unprotected habitat to be along the southwestern border of San Martín and in the northern area of the species' range, between the Zona Reservada Cordillera de Colán and the Bosque de Protección de Alto Mayo (Fig. 2). It was also found that there was a significant difference in deforestation within protected areas (703.8 km²) compared to deforestation outside those areas (24,276 km²).

Based upon remaining suitable habitat in areas of minimal risk, one new protected area, one wildlife corridor, and four extension zones to existing protected areas are suggested (Fig 3). Together these would protect an extra 2,806 km² of *O. flavicauda* habitat (leaving only 1,620 km² or 26% unprotected).

Discussion

No range-wide studies are available for the distribution of *O. flavicauda*. This is mainly due to the rarity of the species, but also to the fact it was thought extinct until its rediscovery in 1974 (Mittermeier *et al.* 1975). Two studies (Leo Luna 1980; Shanee *et al*. 2008) have evaluated a number of sites, but neither covered the entire range of the species. Other occurrence records do exist, but these studies are spread over the last three decades and the older studies are less relevant due to the widespread deforestation since the 1970s. Proper analysis of the actual current distribution of this species is needed to help conserve *O. flavicauda* and its habitat.

The two main threats facing tropical wildlife are hunting and land conversion. Hunting still occurs in Amazonas and San Martín, particularly in native communities but there is considerable opportunistic hunting by immigrant communities (Shanee pers. obs.). Until the 1950's this species was fairly well protected due to the inaccessibility of its habitat. Since the construction of new roads, which began in the 1970's, immigration has resulted in the human population increasing to around 1 million inhabitants. The proliferation of road building and mining concessions in recent years is increasing deforestation, and further contributes to the risks this species faces. This widespread deforestation throughout the species' range has caused fragmentation of the forest, which forces species into smaller areas where competition for resources is more pronounced, access for hunters is facilitated, and connectivity between individual populations reduced, increasing the risk of genetic degeneration from inbreeding.

This study was limited by the paucity of current data from departments other than Amazonas and San Martín but,

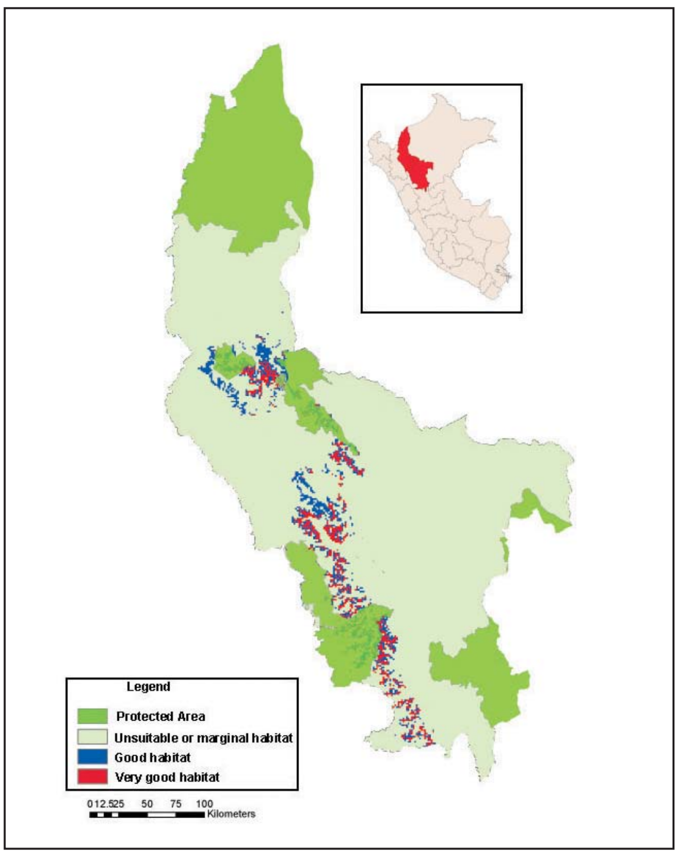

Figure 2. Protected areas network showing gaps in habitat protection for *Oreonax flavicauda.*

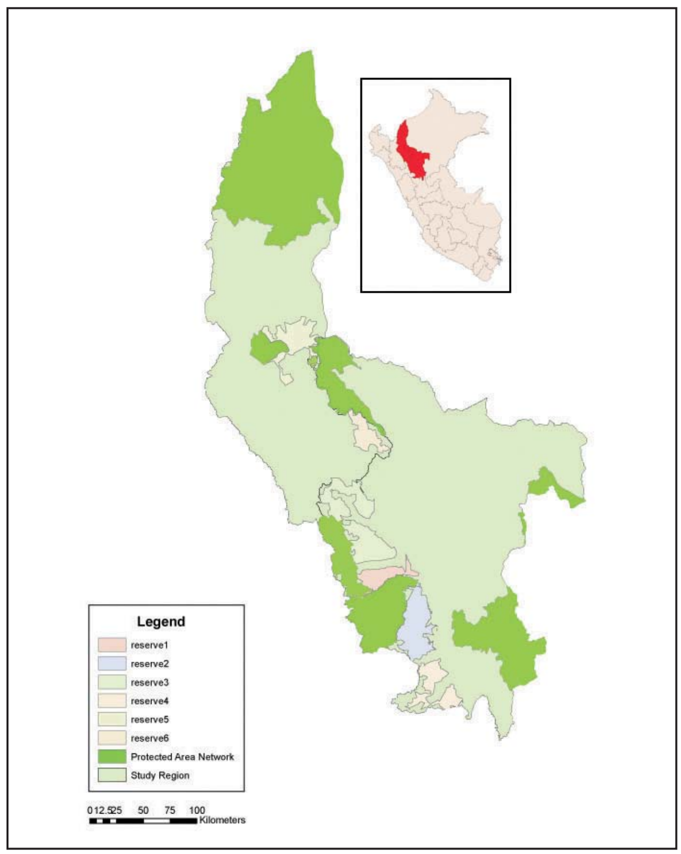

Figure 3. Areas proposed for protected areas for the conservation of *Oreonax flavicauda.*

even so, we feel the results presented here to be valid, as the vast majority of the species' range is within the area covered by our analysis. Gap analysis is a useful tool for wildlife conservation, and has been used effectively for many species (for example, Mariano *et al*. 2006; Smith *et al.* 2003; Tognelli *et al*. 2008) to assess protection levels and park efficiency. This study shows that areas currently protected are fairly efficient in protecting the forest within their boundaries. However, it is clear that deforestation does still occur within them, if at a slower rate than outside their boundaries. This is confirmed by other sources, for example it is estimated that as much as 4,528 ha of forest had been destroyed in the Bosque de Protección de Alto Mayo by the year 2000 (Peru, INRENA 2008), and that between 4,399 (Peru, INRENA 2008) and approximately 5,000 families currently live there (ParksWatch, Peru 2007). This has been attributed to the fact that until recently there were only three park guards employed to protect the 182,000 ha of the park. It is hoped that with the release of the new management plan (Peru, INRENA 2008) the situation will improve. Approximately 70% of *O. flavicauda*'s potential habitat is not currently protected, showing that there are opportunities for expanding the existing PA Network to protect the species. Recommendations concerning this have been published in previous studies (Butchart *et al*. 1995; DeLuycker 2007; Shanee *et al*. 2007).

It was estimated that by 2005 potential forested habitat left in the region would be reduced to 7,240 km² (DeLuycker and Heymann 2007). This study estimated that actual forest loss is higher then expected, and that only 6,302 km² of habitat are still available. For over three decades urgent recommendations have made been for the establishment of new protected areas for this species. This has resulted in the creation of three government reserves, Parque Nacional Río Abiseo (274,500 ha), Bosque de Protección de Alto Mayo (182,000 ha) and the Zona Reservada Cordillera de Colán (64,115 ha), two conservation concessions, Alto Huyabamba (143,928 ha) and Abra Patricia-Alto Nieva (10,000 ha), as well as the several small private conservation areas. We believe that the current PA network in the area is still insufficient because immigration rates in the region are still among the highest in Peru. There are also plans for new private and public reserves, including; a bi-regional conservation area (approximately 300,000 ha) as well as the Huicungo Municipal Conservation Area (92,827 ha) and Breo Conservation Concession (113,722 ha) in the south of San Martín.

The National Protected Area System (*Sistema Nacional de Areas Nacionales Protegidas*) of Peru includes a number of protected area categories, each affording a different level of protection. In the case of *O. flavicauda*, the Parque Nacional Río Abiseo affords the most protection as it is of indirect use only (strict protection). Bosques de Protección, such as Alto Mayo, are a category of so-called "direct use." Limited exploitation of the forest is permitted as long as it does not affect vegetation cover or water courses. Bosques de Protección are often viewed as the lowest form of protection (S. Shanee pers. obs.). A Zona Reservada, such as that of the Cordillera de Colán, is a transitional stage, for areas where the government is as yet unable to determine the appropriate protected status. It is probable that the Zona Reservada Cordillera de Colán will become a Santuario Nacional (Cesar Barta pers. comm.), in which only indirect use is permitted. These are usually created as refuges for the conservation of an individual species, such as *O. flavicauda* (Peru, INRENA 2009). Conservation concessions and private conservation areas are of indirect use, but the status and level of protection afforded depends on the individual management plans.

The creation of reserve three (Fig. 3) in the District of Huicungo, San Martín, would protect the largest area of the Good and Very Good habitat that we identified. The Good and Very Good habitat would also be partially covered by the three proposed reserves and concessions mentioned above (covering an additional 1,632 km² of *O. flavicauda* habitat). Likewise, the creation of a protected corridor between the Bosque de Protección de Alto Mayo and the Zona Reservada Cordillera de Colán in the Province of Bongara, Amazonas, would not only protect a large area of Good and Very Good habitat, but would also ensure future genetic flow between populations in the two protected areas. There are currently two NGOs working in this area; Asociación Ecosistemas Andinas (ECOAN) and Neotropical Primate Conservation (NPC). ECOAN have recently been granted a 10,000-ha conservation concession for lands bordering the Bosque de Protección de Alto Mayo and are involved in developing ecotourism. Neotropical Primate Conservation and the Natural History Museum of San Marcos University are working with the communities of Yambrasbamba and Corosha towards the development of a series of private conservation areas (*Area de Conservación Privada*) to close the gap between protected areas. Both NGOs also promote reforestation in the area, and NPC has education and community assistance programs running in conjunction with conservation work.

There is also a reserve being planned in the cross border region of La Laguna de los Condores in the southeast of Amazonas and west of San Martín. These and other conservation actions will not only protect *O. flavicauda* but also many other endemic and threatened species. Further field studies to properly evaluate other areas highlighted by this study and to develop a detailed map of the species range are set to begin in 2009. We conclude by raising the issue of the necessity and urgency of increasing the size and efficiency of the current PA network in Amazonas and San Martín in order to ensure the survival of the yellow-tailed woolly monkey.

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