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Ecology and Reproductive Behaviour of Rhesus monkeys, *Macaca mulatta* (Zimmerman, 1780)

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Abstract: *Macaques (*Macaca spp.*) are Old World monkeys, with the greatest geographical distribution of all non-human primates, across Asia, Southern Europe and North Africa. There are 22 species; the two most commonly used in research and testing are the cynomolgus macaque (*Macaca fascicularis*) and the rhesus macaque (*Macaca mulatta*). Understanding the life history and behaviour of macaque species is essential for providing the best possible care in captivity and for achieving the best quality science from these animals. Appreciation of life history variables (such as ecological niche, social organisation, developmental stages) and natural behavioural repertoires can help to improve, for example, housing and enrichment design, ease of management of social groups, and the ability to train individuals for voluntary cooperation with scientific procedures, all of which will benefit animal welfare. Macaques that can express a wide range of species-, age- and sex-specific behaviours are more likely to be able to cope with the challenges posed by husbandry and scientific protocols.*
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1. Introduction: The natural habitat of rhesus monkeys (Macaca mulatta) is Asia and of all primate species they, inhabit the largest area. Their habitat stretches from Afghanistan through India, Thailand, Vietnam and China. Since they are extremely adaptable, they can survive the cold high mountain regions in the Himalayans as well as the dry and hot areas of the plains. Usually, they prefer to live in open scrub, forests and parks. Some rhesus monkey clans prefer rocky areas and coastal marshes as their habitat. In areas where their natural habitat has been increasingly restricted, they live with close range of people, which also speaks in favor of their tremendous sense of adaptability. In South Asia, especially in India, they can be found in rural settlements, temples and even cities.

Divided according to country of origin, rhesus macaques are referred to as Chinese-and Indian-derived. Chinese-derived rhesus macaques include subspecies M. m. vestita, M. m. lasiota, M. m. sanctijohannis, and M. m. brevicauda. Indian-derived rhesus macaques are found in other countries besides India, but are still informally referred to as Indian-derived and include M. m. mulatta and M. m. villosa (Smith & McDonough 2005). In breeding colonies at research centers in the United States, rhesus macaques have sometimes been bred separately according to their "country" of derivation but in other cases, crossbreeding has occurred, leading to some confusion about the taxonomic separation of individuals used in research (Smith & McDonough 2005).

Macaca mulatta (rhesus macaques) are very popular as laboratory animals and are used for biomedical and behavioural research in the internatonal trade. In Puerto Rico, the introduction and trade with any species of primates is lllegal. Wild populations of rhesus macaques represent a potential threat to humans, due to their strength and agressiveness, and that they carry diseases that can be transmitted to humans. Rhesus macaques invade fruit farms and eat the produce. Being omnivorous and intelligent, they will catch and eat natives birds (and their eggs), lizards, snakes and other species.

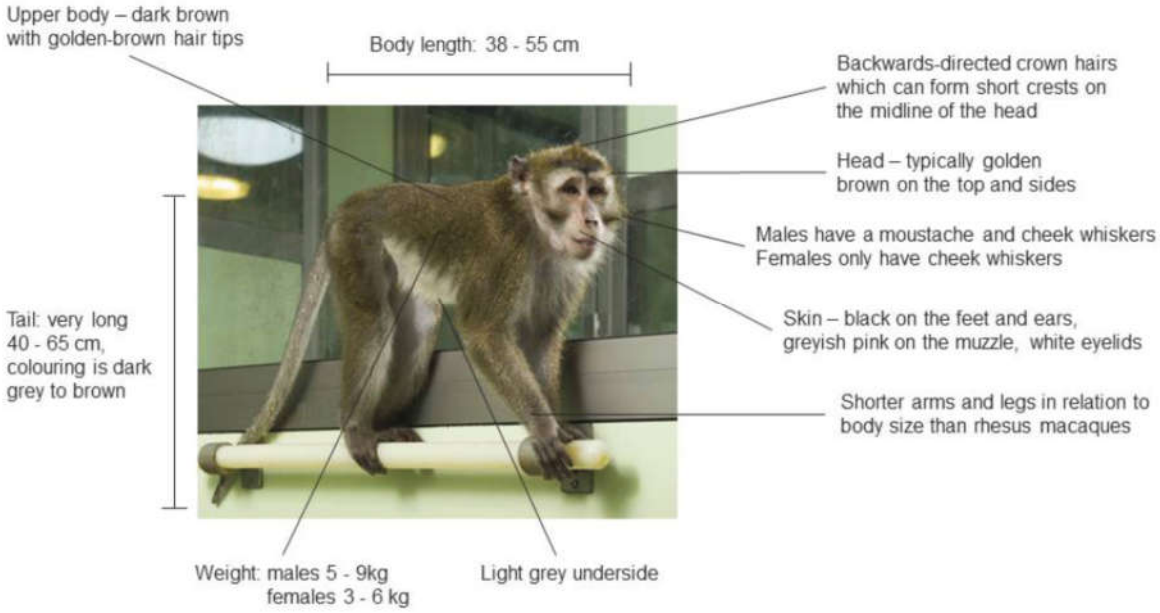
2. Taxonomy

Suborder: Haplorrhini
Infraorder: Simiiformes
Superfamily: Cercopithecoidea
Family: Cercopithecidae
Subfamily: Cercopithecinae
Genus: Macaca
Species: M. mulatta
Subspecies: M. m. brevicauda, M. m. lasiota, M. m. mulatta, M. m. sanctijohannis, M. m. vestita, M. m. villosa

Other names: rhesus monkey; macaque rhésus (French); mono resus (Spanish); rehesusapa or rhesusmakak (Swedish); M. m. lasiota: west Chinese rhesus macaque; M. m. sanctijohannis: insular Chinese rhesus macaque or south Chinese rhesus macaque; M. m. vestita: Tibetan rhesus macaque

3.Description

Adult male rhesus macaques can measure more than 76cm tall and weigh 15kg; adult females are smaller; averaging 47cm in length, and weighing around 5kg. They have a tail that measures between 20 and 23cm long. They have pink-coloured hairless faces, but the rest of their bodies are covered with a brownish-grey coloured fur. Their hands and feet are prehensible with hairless palms with oppossed thumbs. Their upper canine teeth are long and straight, while the lower canines curve inward. They have callous, hairless buttocks.



They can live up to 25 years. (Álvarez-Romero & Medellín, 2005). Rhesus macaques, both Chinese- and Indian-derived, range in color from dusty brown to auburn with little to no fur found on their reddish-pink faces. Their rumps are the same color as their faces and they have medium-length tails that average between 207.6 and 228.9 mm (8.17 and 9.01 in) (Fooden 2000). Males and females are sexually dimorphic, like other species of macaques, and males measure, on average, 531.8 mm (1.74 ft) and weigh, on average, 7.70 kg (17.0 lb) while females have an average height of 468.8 mm (1.54 ft) and an average weight of 5.34 kg (11.8 lb) (Fooden 2000; Singh & Sinha 2004). They are quadrupedal and, depending on the type of habitat in which they are found, can be predominantly arboreal or predominantly terrestrial (Seth et al. 2001). Rhesus macaques are also skilled swimmers and have been observed crossing bodies of water up to one kilometer (.621 mi) wide. When they are seen in the water they are usually searching for food, escaping from danger, regulating their body temperature, or playing. Swimming is a skill seen in infants as young as two days old (Fooden, 2000).

4. Habitat description

Rhesus macaques are adapted to a variety of habitats from tropical coastal lowlands to snowy mountain valleys 2,500m above sea level, from dense tropical forest, to temperate pine grooves, to semi-desert conditions. They are opportunistic omnivores, although they prefer fruit. They are excellent swimmers and enjoy living next to water bodies. They prefer living on trees, but descend to floor level to forage in search of food. They are intelligent, social and gregarious and adapt easily to life among humans and domestic animals, if tolerated. However, they are territorial and aggressive and attack in groups whenever they feel threatened. (Álvarez-Romero & Medellín, 2005).

The only primates with a broader geographic distribution than rhesus macaques are humans (Southwick et al. 1996). Rhesus macaques are found ubiquitously throughout mainland Asia; from Afghanistan to India and Thailand to southern China (Rowe 1996; Smith & McDonough 2005). M. m. vestita, M. m. lasiota, and M. m. sanctijohannis are found in western, central, and eastern China, respectively (Groves 2001; Smith & McDonough 2005). Another Chinese species of rhesus macaque, M. m. brevicauda, is found on Hainan Island, off the southwest coast of China. The Indian-derived rhesus macaques are separated by region with M. m. villosa found in the Kashmir and Punjab region of India (the northern part of the country), Pakistan, and Afghanistan and M. m. mulatta found in India, Bhutan, Burma, Nepal, Bangladesh, Thailand, Laos, and Vietnam (Groves 2001; Smith & McDonough 2005). It is likely that there will be additional subspecies added and M. m. mulatta will be reclassified into several

more distinct subspecies based on genetic and morphological differences (Groves 2001).

A free-ranging colony of rhesus macaques was established in 1938 on an island in the Caribbean. Introduced to Cayo Santiago, Puerto Rico, rhesus macaques have been studied under semi-natural conditions for almost 70 years and have provided an unprecedented resource for information about behavior, population demography, and long-term histories of individuals' social and physical development (Rawlins & Kessler 1986a). Furthermore, with the establishment of this colony of free-ranging macaques came the birth of a new field of study, sociobiology, pioneered by Stuart Altmann who observed rhesus monkeys on Cayo Santiago and worked with notable sociobiologist E.O. Wilson (Bercovitch pers. comm.).

Rhesus macaques are the most studied nonhuman primate, both in the field and in laboratory settings, though most of the field research comes from rhesus macaques in India (Richard et al. 1989). One of the notable early field researchers of rhesus monkeys is Charles Southwick, who began surveying them in 1959 (Seth 2000). Donald Lindburg has been another force in rhesus macaque studies, assessing the abundance of rhesus in India as well as reporting declines in the population which was important at the time of their export (Seth 2000; Smith & McDonough 2005).

In India, rhesus macaques are found in flat, cultivated areas, where agricultural fields dominate the landscape and in the plains, foothills and mountainous regions where habitat includes cultivated fields, tropical forests and dry, deciduous forests. Average annual rainfall ranges between 420 and 2150 mm (1.38 and 7.05 ft), depending on elevation, and annual range in temperature is between -4° C (25° F) and 48° C (118° F) (Seth & Seth 1986). During the hottest parts of the year, groups in the Himalayan region of India migrate to higher elevations where cooler temperatures persist throughout the summer months (Seth et al. 2001). In urban areas of India, they are found on roadsides, canal banks, in railway stations, villages, towns, and temples (Richard et al. 1989). It is estimated that 48.5% of rhesus macaques in northern India live in villages, towns, cities, temples and railway stations where they are in close and frequent contact with people at all times. About 37.1% of the population lives with some human contact on roadsides and canal banks and only 14.4% of the rhesus macaques in the northern part of the country live in isolation from humans and do not rely on them at all for food (Southwick & Siddiqi 1994).

Because they are found in such a broad geographic area, it is difficult to concisely summarize the types of habitats rhesus macaques populate. In the most general terms, they are found in both tropical and temperate habitats including semidesert, dry deciduous, mixed deciduous and bamboo, and temperate forests as well as in tropical forests and mangrove swamps, usually at elevations from sea level to 2000 m (6561 ft), but they have been seen at elevations up to 4000 m (13,123 ft) in China and northeastern India (Seth & Seth 1986; Fooden 2000; Srivastava & Mohnot 2001). Rhesus macaques are also found in areas close to humans in urban settings or near cultivated fields (Southwick et al. 1996).

In the northernmost part of their range, the rhesus of the Taihang Mountains in China live in a secondary deciduous forest at elevations between 300 and 1200 m (984 and 3937 ft) with a temperate climate and cold, snowy winters similar to the climate of the central, Midwestern United States (Qu et al. 1993). In this region, there are hot, rainy, and humid summers with severely cold and dry winters, and temperatures ranging between -20° C (-4° F) and 40° C (104° F) during the year. Annual rainfall averages 641 mm (2.10 ft), with the rainiest period lasting from June to August (Qu et al. 1993). This is similar to the climate of the region of Pakistan where they are found, but the habitat in Pakistan is dominated by mixed evergreen and deciduous forests that are highly disturbed (Goldstein & Richard 1989). In their tropical range in China, and similarly in Burma, Laos and Thailand, the rainy season lasts from May to October with annual rainfall averaging 1575 mm (5.17 ft). Temperature is more stable in India and northern China throughout the year, ranging between 22° C (72° F) and 28° C (82° F). The habitat includes primary and secondary tropical and dry evergreen forests and bamboo forests (Jiang et al. 1991; Southwick et al. 1996; Borries et al. 2002).

5. Ecology

Rhesus macaques are exceptionally adapted to coexisting with humans and thrive near human settlement, in both urban and agricultural areas. It is impossible to characterize their "natural" diet without considering the impact of humans. Because they are found in higher densities in areas of human disturbance compared to forests, in some areas rhesus macaques derive, both directly and indirectly, a substantial part of their diet from human activities (Richard et al. 1989). In fact, up to 93% of their diet can be from human sources, either from direct handouts or from agricultural sources (Southwick & Siddiqi 1994). Rhesus macaques are omnivores and feed on a wide array of plant and invertebrate products. By raiding crops, they have access to a huge variety of cultivated fruits and vegetables, and in highly urban areas, they forage by picking through garbage (Goldstein & Richard 1989; Richard et al. 1989). Throughout their range and especially in India, they inhabit temples and are fed as a form of worship by local people (Wolfe 2002). Some of the most common foods given to rhesus macaques in temples include bread, bananas,

peanuts, seeds, other fruits and vegetables, and assorted miscellaneous foods like ice cream and fried bread (Wolfe 1992). In less human-influenced areas, they focus on fruits, flowers, leaves, seeds, gums, buds, grass, clover, roots, bark, and they supplement their diet with termites, grasshoppers, ants, beetles, and mushrooms. Rhesus macaques also eat bird eggs, shellfish, and fish (Fooden 2000). During the driest parts of the year, they may even eat the dirt from termite mounds (Lindburg 1971). On Cayo Santiago, the rhesus macaques also consume dirt possibly because the mineral composition of the soil on the island is similar to pharmaceuticals used in humans to treat upset stomach. The Cayo rhesus may be eating dirt to relieve the discomfort associated with intestinal parasites (Knezevich 1998). At higher elevations, where seasonal snowfall restricts food sources, rhesus macaques are restricted to eating the leaves of evergreen trees and bark as well as a few berries that grow in winter. During the winter months at high elevations, rhesus macaques suffer from food and climate stress and have higher levels of mortality if the cold weather lasts too long (Qu et al. 1993).

Home range size and day range length are dependent on habitat in rhesus macaques. Temple, village, and urban rhesus macaques have small home ranges between .01 and 3.0 km² (.004 and 1.16 mi²) in size because they derive almost all of their food from human visitors leaving offerings, crop raiding, or opportunistic foraging on human byproducts (Seth & Seth 1986). The day ranges for these urbanized areas are variable but the average is about 1.15 km (.715 mi) (Fooden 2000). In more forested areas of India, home range size can be up to 15 km² (5.79 mi²), but rhesus monkeys only move, on average, 1428 m (.887 mi) per day (Lindburg 1971). In China, home ranges vary in size from .1 to .72 km² (.039 to .278 mi²) near villages, while in mountainous areas, home ranges are much larger and span between 11 and 22 km² (4.25 and 8.49 mi²) but average 16 km² (6.18 mi²) (Southwick et al. 1996). Daily path lengths in this environment range from 1050 to 3500 m (.652 to 2.17 mi) (Makwana 1978).

Both climate and season affect the timing of the onset of daily activities as well as the type of activities undertaken. In the warmest times of the year, rhesus macaques spend more time resting than during more temperate months (Seth & Seth 1986; Seth 2000). Home ranges of rhesus macaques overlap and groups have high frequencies of intergroup contact, which is characterized by generally mild social interactions (Melnick et al. 1984). Across all habitat types, feeding and resting are the major activities of the rhesus macaques' day and they spend the rest of their time traveling, grooming, playing, and other activities (Seth & Seth 1986).

Potential predators of rhesus macaques include raptors, dogs, weasels, leopards, tigers, sharks, crocodiles, and snakes (Fooden 2000).

5.1. Diet

Rhesus monkeys are omnivores. Their diet consists mainly of plant material. Their meat diet derives mostly in the form of insects, spiders, crustaceans and bird's eggs. In wetlands, they catch and eat fish. Near human settlements they frequently plunder fields and gardens with grown crops or search garbage cans for edibles.

5.2. Lifestyle

Rhesus monkeys are highly vivacious and active animals. They live in groups of 20 to 200 animals and live on the ground or in trees depending on the habitat. They spend most of the day with foraging and eating. Rhesus monkeys run on the ground on all fours and are good climbers and jumpers. They like to bath and are therefore good swimmers. The size of their home ranges is highly variable and could encompass the size of a few hundred meters to several kilometers. Although rhesus monkeys live in group association, they are not very territorial. The individual areas of neighboring groups can overlap significantly but since the outnumbered group rapidly withdraws during confrontations, hostilities are rare.

5.3. Population Size and Structure

Rhesus macaques live in matrilineal social groups consisting of adult females and their offspring, a single adult alpha male, and subordinate adult males. Females remain with their natal group their entire lives. Males typically emigrate from their natal group upon reaching sexual maturity, after which they will live in solitude or as part of a bachelor group before joining another social group. Sex ratio within social groups is three females to one male on average. Group size and population density is related to food abundance. Average group size is 32.2 individuals in non or minimally food-provisioned populations and 75 individuals in food-provisioned populations (Fooden, 2000).

5.4 Social behavior and reproduction

The rhesus monkey groups consist of several males, females and young animals. Hierarchies are formed from in both sexes, whereby those of the females are more stable and lasting than those of the males. The females remain in their birth group, while the males form small bachelor groups and leave the group when they reach sexual maturity. Mating takes place between members of equal ranking in the group. However, the reproductive behavior of rhesus monkeys is characterized by promiscuity. Females reach sexual maturity with three and a half to five and a half years, males slightly later with six and a half years. The mating times vary and are dependent on the habitat. Rhesus monkeys that live in cold-winter areas usually

mate in the fall. The infants are therefore born during the spring time. In the lowlands, reproduction is dependent on the monsoon season. Births occur most frequently in the pre - and post monsoon period. (March - June and September - October). After a gestation period of about 166 days, the female gives birth to a baby that weighs between 450 and 500 grams. During the first weeks the infant is carried around on the belly or on the back of the mother who intensively cares for it. After two weeks the infants are ready to take solid food and after six months, it can take care of itself.

6. Rhesus monkeys in research

Rhesus monkeys have long been used as experimental research animals. In 1940, the rhesus factor, named after them was discovered in their blood. The rhesus factor was later found in humans. This important finding henceforth prevented fatal immune reactions in blood transfusions and during pregnancy. Through experiments on rhesus monkeys, scientists were able to develop the vaccine against the poliovirus in the fifties, where today millions of people are protected from infection. Through the consequent massive export of rhesus monkeys from India to the respective destination countries, their populations decreased rapidly at times. Around the end of the seventies, the Indian government stopped the export of monkeys in order for the population growth to recover. Rhesus monkeys for research are nowadays bred in special facilities such as the German Primate Center with high sanitary standards and are therefore no longer removed from their natural habitat. Worldwide, rhesus monkeys are primarily used as experimental animals in infection research, drug development and in brain research. In 2007, the result of the DNA sequencing of the rhesus monkey genome was published in the journal Science. Followed by humans and chimpanzees, rhesus monkeys are the third fully sequenced primate. The scientists were able to show a 93.5 percent compliance of the rhesus monkey DNA with that of man.

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