

= Cotton @-@ top tamarin =

The cotton @-@ top tamarin ( *Saguinus oedipus* ) is a small New World monkey weighing less than 0 @. @ 5 kg ( 1 @. @ 1 lb ) . One of the smallest primates , the cotton @-@ top tamarin is easily recognized by the long , white sagittal crest extending from its forehead to its shoulders . The species is found in tropical forest edges and secondary forests in northwestern Colombia , where it is arboreal and diurnal . Its diet includes insects and plant exudates , and it is an important seed disperser in the tropical ecosystem .

The cotton @-@ top tamarin displays a wide variety of social behaviors . In particular , groups form a clear dominance hierarchy where only dominant pairs breed . The female normally gives birth to twins and uses pheromones to prevent other females in the group from breeding . These tamarins have been extensively studied for their high level of cooperative care , as well as altruistic and spiteful behaviors . Communication between cotton @-@ top tamarins is sophisticated and shows evidence of grammatical structure , a language feature that must be acquired .

Up to 40 @, @ 000 cotton @-@ top tamarins are thought to have been caught and exported for use in biomedical research before 1976 , when CITES gave them the highest level of protection and all international trade was banned . Now , the species is at risk due to large @-@ scale habitat destruction , as the lowland forest in northwestern Colombia where the cotton @-@ top tamarin is found has been reduced to 5 % of its previous area . It is currently classified as critically endangered and is one of the rarest primates in the world , with only 6 @, @ 000 individuals left in the wild .

= = Taxonomy and naming = =

*Saguinus oedipus* has the common names " cotton @-@ top tamarin " and " cotton @-@ headed tamarin " in English . Its name comes from the white hair that spans its head and flows down past the neck . In Spanish , *S. oedipus* is commonly called *bichichi* , *tití pielroja* , " *tití blanco* , *tití cabeza blanca* , or *tití leoncito* . In German @-@ speaking areas , the cotton @-@ top tamarin is commonly known as *Lisztaffe* ( literally " Liszt monkey " ) most likely due to the resemblance of its hairstyle with that of Hungarian composer and piano virtuoso Franz Liszt .

The species was first described by Linnaeus in 1758 as *Simia oedipus* . Linnaeus chose the species name *oedipus* , which means swollen foot , but as the species does not have particularly large feet , it is unknown why he chose this name . ( Linnaeus often selected names from mythology without any particular rationale , and he may have used the name of *Oedipus* , the mythical Greek king of Thebes , more or less arbitrarily . ) In 1977 , Philip Hershkovitz performed a taxonomic analysis of the species based on fur coloration patterns , cranial and mandibular morphology , and ear size . He classified Geoffroy 's tamarin *S. geoffroyi* as a subspecies of *S. oedipus* . Subsequent analyses by Hernández @-@ Camacho and Cooper ( 1976 ) , Mittermeier and Coimbra @-@ Filho ( 1981 ) , and later Grooves ( 2001 ) consider the *S. oedipus* and *S. geoffroyi* types to be separate species .

Some researchers , such as Thorington ( 1976 ) , posit that *S. oedipus* is more closely related to the white @-@ footed tamarin ( *S. leucopus* ) than to *S. geoffroyi* . This view is supported by Hanihara and Natoria 's analysis of toothcomb dental morphology ( 1987 ) and by Skinner ( 1991 ) , who found similarities between *S. oedipus* and *S. leucopus* in 16 of 17 morphological traits considered .

This species of white @-@ headed tamarin is thought to have diverged from the other Amazonian forms such as *S. leucopus* . This is supported by morphological considerations of the transition from juvenile to adulthood , during which the fur coloration patterns change significantly and are similar between the two species . Hershkovitz proposed that the separation of the two species happened in the Pleistocene at the height of the Atrato River , where it intersected the Cauca @-@ Magdalena . At that time , the area was covered by a sea , which created a geographic barrier that caused the species to diverge through the process of allopatric speciation . Today , the two species are principally separated by the Atrato River .

= = Physical characteristics = =

The cotton @-@ top tamarin is part of the most diminutive family of monkeys , Callitrichidae , the marmosets and tamarins ; it weighs 432 g ( 15 @.@ 2 oz ) on average . Its head ? body length is 20 @.@ 8 ? 25 @.@ 9 cm ( 8 @.@ 2 ? 10 @.@ 2 in ) , while its tail ? which is not prehensile ? is slightly longer at around 33 ? 41 cm ( 13 ? 16 in ) . The species is not sexually dimorphic , the male and female are of a similar size and weight . Members of the Callitrichinae subfamily ( including this species ) have sharp nails ( tegulae ) on all digits except the big toes , which have the flat nails ( ungulae ) common to other primates . Tegulae resemble a squirrel 's claws and help with movement through trees .

The cotton @-@ top tamarin has a long sagittal crest , consisting of white hairs , from forehead to nape flowing over the shoulders . The skin of the face is black with gray or white bands located above the eyes . These bands continue along the edge of the face down to the jaw . Tamarins are generally divided into three groups by their facial characteristics : hairy @-@ faced , mottled @-@ faced , and bare @-@ faced . The cotton @-@ top tamarin has fine white hairs covering its face , but they are so fine as to appear naked , thus is considered a bare @-@ faced tamarin . Its lower canine teeth are longer than its incisors , creating the appearance of tusks . Like other callitrichids , the cotton @-@ top tamarin has two molar teeth on each side of its jaw , not three like other New World monkeys .

The cotton @-@ top tamarin has fur covering all of the body except the palms of the hands and feet , the eyelids , the borders of the nostrils , the nipples , the anus , and the penis . The back is brown , and the underparts , arms and legs are whitish @-@ yellow . The rump and inner thighs and upper tail are reddish @-@ orange . The fur is distributed with varying densities throughout the body : the genital region ( scrotum and pubic zone ) , axilla , and the base of the tail have lower densities , while the forward region is much higher . Many individuals have stripes or whorls of fur of striking coloration on their throats . The cotton @-@ top also has whiskers on its forehead and around its mouth .

= = Habitat and distribution = =

The cotton @-@ top tamarin is restricted to a small area of northwest Colombia , between the Cauca and Magdalena Rivers to the south and east , the Atlantic coast to the north , and the Atrato River to the west . They mostly live Brazil , 2 / 3 of there habitat has been destroyed . Historically , the entirety of this area was suitable for the cotton @-@ top tamarin , but due to habitat loss through deforestation , it survives in fragmented parks and reserves . One of the most important areas for the cotton @-@ top is the Paramillo National Park , which consists of 460 @,@ 000 hectares ( 1 @,@ 800 sq mi ) of primary and secondary forest .

The cotton @-@ top tamarin is found in both primary and secondary forests , from humid tropical forests in the south of its range to tropical dry forests in the north . It is seldom found at altitudes above 400 metres ( 1 @,@ 300 ft ) , but has been encountered up to 1 @,@ 500 metres ( 4 @,@ 900 ft ) . It prefers the lower levels of the tropical forests , but may also be found foraging on the ground and anywhere between the understory and the canopy . It can adapt to forest fragments and can survive in relatively disturbed habitats . In the dry forests are pronounced seasons . Between December and April , it is dry , while heavy rainfall occurs between August and November which can flood the forest floor . Across its range , annual rainfall varies between 500 and 1 @,@ 300 mm ( 20 and 51 in ) .

= = Ecology = =

The cotton @-@ top tamarin has a diet of mainly fruit ( 40 % ) and animal material ( 40 % ) . This includes insects , plant exudates such as gum and sap , nectar , and occasionally reptiles and amphibians . Due to its small body size and high food passage rate , its diet must be high @-@ quality and high @-@ energy . Insectivory is common in the cotton @-@ top and the species hunts for insects using a variety of methods : stealth , pouncing , chasing , exploring holes , and turning

over leaves .

Tamarins act as seed dispersers in tropical ecosystems . While larger primates eat larger seeds , tamarins eat the smaller ones . The expelled seeds have a higher germination rate than others and ingesting larger seeds may help to dislodge and expel intestinal parasites .

The cotton @-@ top tamarin is diurnal and sleeps with its social group in trees with foliage cover . The group leaves the sleeping tree together an hour after dawn and spends the day foraging , resting , travelling , and grooming . The species is thought to rise late and increases the speed of its foraging and travelling before dusk to avoid crepuscular and nocturnal predators . Its main predators include raptors , mustelids , felids , and snakes . The cotton @-@ top tamarin is extremely vigilant , always looking for potential predators . When the group is resting , one individual moves apart and acts as a lookout to alert the group if it sees a threat .

The cotton @-@ top tamarin can live as long as 24 years in captivity , while its lifespan in the wild averages 13 years .

= = Behavior = =

= = = Social systems = = =

The cotton @-@ top tamarin is a highly social primate that typically lives in groups of two to nine individuals , but may reach up to 13 members . These small familial groups tend to fluctuate in size and in composition of individuals and a clear dominance hierarchy is always present within a party . At the head of the group is the breeding pair . The male and female in this pair are typically in a monogamous reproductive relationship , and together serve as the group 's dominant leaders .

Dominant pairs are the only breeding pair within their groups , and the female generally has authority over the breeding male . While nonbreeding group members can be the leading pair 's offspring , immigrant adults may also live with and cooperate in these groups . This social grouping in cotton @-@ top tamarins is hypothesized to arise from predation pressure . Cotton @-@ top tamarins exhibit prosocial behavior that benefits other members of the group , and are well known for engaging in cooperative breeding whereby the group 's subordinate adults help in rearing the offspring of the dominant pair . The dominant female is more likely to give birth to nonidentical twins than a singleton , so it would be too energetically expensive for just one pair to raise the young .

To prevent younger , subordinate females within the group from breeding , the dominant female uses pheromones . This suppresses sexual behavior and delays puberty . Unrelated males that join the group can release the females from this reproductive suppression ; this may result in more than one female of the group becoming pregnant , but only one of the pregnancies will be successful .

= = = = Cooperation = = = =

In cooperative breeding , the effort put into caring for the dominant breeders ' offspring is shared by the group members . Parents , siblings , and immigrant adults share young rearing duties for the breeding pair 's young . These duties include carrying , protecting , feeding , comforting , and even engaging in play behavior with the group 's young . Cotton @-@ top tamarins display high levels of parental investment during infant care . Males , particularly those that are paternal , show a greater involvement in caregiving than do females . Despite this , both male and female infants prefer contact and proximity to their mothers over their fathers . Males may invest additional support in rearing offspring as a form of courtship to win favor of the group 's dominant female . However , evidence indicates that time spent carrying infants does not correlate with a male 's overall copulation frequency .

Since only one female in a group breeds , heavy investment in infant care ensures that all offspring survive until independence . Accordingly , cotton @-@ top tamarins bear excessive costs to care for the group 's young . Male carriers , especially paternal carriers , incur large energetic costs for the sake of the group 's young . This burden may cause some male cotton @-@ tops to lose up to 10

@-@ 11 % of their total body weight . The large weight loss may occur from reduced food intake as infant @-@ carrying inhibits foraging ability for a carrier . The trend of male @-@ carrier weight loss and decreased food intake is in contrast to the dominant female 's periovulatory period , when she gains weight after increasing her own food intake and relinquishing much of her infant @-@ carrying duties .

= = = = Altruism = = = =

While caregiving by males appears to be altruistic , particularly in cotton @-@ top sires , the costs of infant care may in fact be tolerated for selfish reasons . Namely , the costs to male weight and foraging ability may in turn promote consecutive pregnancies in dominant females , thereby providing more offspring bearing the sire 's genes . Additionally , the cooperative breeding structure of cotton @-@ tops can change with group size and parental experience . First @-@ time sires spend a greater amount of time carrying the infant than experienced ones , and in smaller groups , sires do a greater proportion of carrying and feeding the infant than in larger groups , where helpers take on more of the work . Total care for infants remains constant with varying group size , and infant outcome is not significantly different in groups that have differing levels of experience in raising offspring .

The cooperative breeding hypothesis predicts that cotton @-@ top tamarins engage with this young @-@ rearing paradigm , and in turn naturally embrace patterns of prosocial behavior . These monkeys engage in such behavior by acting altruistically within their groups in caring for infants , vocalizing alarm calls , and in sharing food . Though some studies indicate that cotton @-@ top tamarins have the psychological capacity to participate in reciprocally mediated altruism , it is unclear whether the cotton @-@ top tamarin acts solely using judgements on reinforcement history .

Other studies involving cotton @-@ top tamarins have hinted that positive reciprocity and reciprocal altruism are irrelevant in the prosociality of these primates . Some researchers believe these primates tend to cooperate for selfish reasons and in situations where they incur some benefit for themselves . That is , cooperation in cotton @-@ top tamarins can be better described by mutualism than by true altruism .

Tamarins in captivity have shown the ability to distinguish other individuals based on cooperative tendencies and past behavior . Cotton @-@ tops ultimately use this information to guide future cooperation . Brief periods of defection tend to cause swift , irreparable breakups between these primates and their cooperators . To avoid this , cotton @-@ top tamarins may make economically driven decisions based on the projected incentives of a potential cooperator .

= = = = Spite and aggression = = = =

Despite an expansive array of altruistic behaviors , cotton @-@ top tamarins engage in great bouts of spite through negative reciprocity and punishment . They have been observed to immediately start denying cooperation with monkeys that deny them benefits . Further , in captivity , these primates are not observed to increase altruistic behavior with fellow primates that are committed fully to cooperation . Based on this , researchers believe that repeated interactions in a cooperative society like that of the cotton @-@ top tamarin can heighten the chances that an individual will designate behavioral punishments to others in its group . This reaction has also been observed in other species . However , these reciprocal punishments , or relative lack of altruistic actions , may alternatively happen as a result of response facilitation that increases the chances of a cotton @-@ top punishing another primate after watching that individual perform a similar action .

Another way to look at punishment in cotton @-@ top tamarins is by observing their aggressive behavioral responses within and between groups , as well as between species . The cotton @-@ top tamarin , like many marmosets , other tamarins , and specifically those in the genus *Saguinus* , stages aggressive displays almost exclusively towards fellow monkeys that belong to the same gender . These intrasexual displays of aggression are more frequent in females , and are vital when

a breeding female is forcing both subadult and adult females to emigrate out of a familial group .

Though aggression can occur within groups , the response towards intruders of another species is much more drastic and can involve a sexual dimorphism in displays . Females typically employ scent @-@ marking intruder response tactics , whereas males are more prone to vocalizing threats , physical aggression , and piloerection . Scent @-@ marking in cotton @-@ top tamarins is done in two ways : either using anogenital scent @-@ marking , or suprapubic scent @-@ marking . The ability to use both of these separate glandular fields for threat signals may indicate females have developed diverging evolutionary threats through differential use of these markings . These variable signals may be used to sign a territorial encounter , or serve as a reproductive signal . The intensity of female threats are generally comparable when directed at intruders of either genders . In contrast , male cotton @-@ tops are considerably more threatening towards fellow males than towards females .

= = = Communication = = =

The cotton @-@ top tamarin vocalizes with bird @-@ like whistles , soft chirping sounds , high @-@ pitched trilling , and staccato calls . Researchers describe its repertoire of 38 distinct sounds as unusually sophisticated , conforming to grammatical rules . Jayne Cleveland and Charles Snowdon performed an in @-@ depth feature analysis to classify the cotton @-@ top 's repertoire of vocalizations in 1982 . They concluded that it uses a simple grammar consisting of eight phonetic variations of short , frequency @-@ modulated " chirps " ? each representing varying messages ? and five longer constant frequency " whistles " . They hypothesize that some of these calls demonstrate that the cotton @-@ top tamarin uses phonetic syntax , while other calls may be exemplars of lexical syntax usage . Each type of call is given a letter signifier ; for example , C @-@ calls are associated with finding food and D @-@ calls are associated with eating . Further , these calls can be modified to better deliver information relevant to auditory localization in call @-@ recipients . Using this range of vocalizations , the adults may be able to communicate with one another about intention , thought processes , and emotion , including curiosity , fear , dismay , playfulness , warnings , joy , and calls to young .

= = = Language acquisition = = =

Over the first 20 weeks after a cotton @-@ top tamarin is born , it is not fully capable of producing the range of vocalizations that an adult monkey can . Despite this limitation on speech producibility , researchers believe that language acquisition occurs early on with speech comprehension abilities arising first . Infants can at times produce adult @-@ like chirps , but this is rarely done in the correct context and remains inconsistent across the first 20 weeks of life . Regardless , infant cotton @-@ tops are able to respond in behaviorally appropriate ways to varying contexts when presented with adult chirps . This indicates that verbal perception is a quickly acquired skill for offspring , followed closely by auditory comprehension , and later by proper vocal producibility .

Castro and Snowdon ( 2000 ) observed that aside from inconsistent adult @-@ like chirping , cotton @-@ top infants most often produce a prototype chirp that differs in vocalization structure from anything seen in the full adult range of vocalizations . Infants are thought to imitate adult speakers , which use differing calls in various contexts , but by using solely the infant prototypical chirp . For instance , adult cotton @-@ tops are known to significantly reduce the amount of general alarm calling in the presence of infants . This is likely adapted so that adults in close proximity to the group 's young do not attract attention of predators to infant @-@ dense areas . Additionally , infants reduce their prototype chirping in the presence of predators . Whether infants are shadowing the calling behavior of adults or they are comprehending danger remains unclear . However , researchers argue that young cotton @-@ top tamarins are able to represent semantic information regardless of immature speech production .

To confirm the notion that language acquisition occurs as a progression of comprehension before production , Castro and Snowdon ( 2000 ) showed that infants respond behaviorally to vocalizing

adults in a fashion that indicates they can comprehend auditory inputs . When an adult produces a C @-@ call chirp , used to indicate food preference and when navigating to a food source , an infant approaches the adult caller to be fed , but do not use the prototype calling as a proxy for C @-@ calls . This finding argues for the idea that infants are able to understand vocalizations first , and later acquire the ability to communicate with adult vocalizations .

= = = = General calling = = = =

Among the typical cotton @-@ top tamarin communicative vocalizations , the combination long call ( CLC ) and the alarm call ( AC ) are the most heavily represented in the literature . CLCs encompass a range of contact calls that are produced by isolated individuals using chirps and whistles . This type of call is also used for seemingly altruistic alarm calls , thus adding to its range of cooperative behaviors . It is issued in the presence of kin when a threatening llamas predator is seen . Predators of the cotton @-@ top tamarin include snakes , ocelots , tayras , and most notably , hawks . Early observations by Patricia Neyman even showed that cotton @-@ tops produce diverse sets of alarm calls that can discriminate the presence of birds of prey versus ground @-@ based predators .

CLCs involve the production of complex sequence multisyllabic vocalizations . Researchers have argued that long calls exhibit individual differences , thus can carry information sufficient for recipients to determine caller identity . Using habituation @-@ discrimination paradigms in language experiments , this theory has been confirmed multiple times in literature . However , the individual syllables within a complete CLC vocalization in isolation of each other do not transfer sufficient information to communicate messages between monkeys . Scientists thus consider the whole , intact string of vocalizations to be the unit of perception for CLCs in the cotton @-@ top tamarin . These examinations may confirm that cotton @-@ tops incorporate a lexical syntax in areas of their communication .

Since tamarins can discriminate between predatory threats using varying vocalizations , recipients of an AC are thought to extract various complex signals from this form of communication . Primarily , cotton @-@ tops are able to glean the identity of the cooperating tamarin through differences in individuals ' alarm calls . Further , adults are able to discriminate the gender of callers from their ACs and determine the range of calls within a related tamarin 's alarm calling repertoire . Alarm call @-@ based identification is postulated to play a number of functional roles in the cotton @-@ top tamarin . Firstly , an AC recipient is able to identify a cooperating tamarin , and by recognizing which in their group it is , be able to judge the reliability of the AC from past experience . This may arise from a selective pressure for being able to statistically determine the amount of risk present , and how endangered an individual and its group are .

Additionally , being able to localize auditory signals may help determine predator location , especially in the presence of a second AC from a different tamarin in the group . This can help confirm predator presence , type ( e.g. flying versus ground @-@ based ) , and support the recipient in triangulating a predator 's location . In the context of the cotton @-@ top 's cooperative breeding groups , this is postulated as being adaptive for determining the variable risk to one 's group members . For example , a call recipient is able to determine which of its kin are and are not at risk ( e.g. young offspring , mates , subordinates , relatives , carriers , etc . ) and plan subsequent actions accordingly .

= = = = Food calls = = = =

The cotton @-@ top tamarin makes selective , specialized vocalizations in the presence of food . These include the C @-@ call , produced when a cotton @-@ top approaches and sorts through food , and the D @-@ call , which is associated with food retrieval and is exhibited while eating .

C @-@ call chirping is believed to be an honest signal for communicating food preference , and a cotton @-@ top tamarin more often and more rapidly vocalizes with these chirps when approaching a highly favored food source . Functionally , this behavior may inform other tamarins of the actions

the caller will take in a feeding context and whether a preferable food source is available . Despite this research indicating that food calls may be informative to fellow group mates , other observations of cotton @-@ tops show that quantity and distribution of food and audience do not significantly alter a caller 's food @-@ centered vocalizations .

The cotton @-@ top tamarin is seen to produce food calls both in the presence and absence of group members . Additionally , response to food calls are directed back to an original caller independent of visual confirmation of a food source . While this may appear to be a result from a very primitive form of communication , Roush and Snowden ( 2005 ) maintain that the food @-@ calling behavior confers some mentally representable information about food to recipient tamarins .

= = Conservation status = =

The wild population is estimated at 6 @,@ 000 individuals , with 2 @,@ 000 adults . This species is critically endangered , and was listed in the " The World 's 25 Most Endangered Primates between 2008 and 2012 . " The publication lists highly endangered primate species and is released every two years by the International Union for Conservation of Nature Species Survival Commission Primate Specialist Group . The cotton @-@ top tamarin was not selected for the 2012 ? 2014 publication .

Habitat destruction through forest clearing is the main cause of this collapse , and the cotton @-@ top has lost more than three @-@ quarters of its original habitat to deforestation , while the lowland forest in which it lives has been reduced to 5 % of its historical range . This land is then used for large @-@ scale agricultural production ( i.e. cattle ) and farming , logging , oil palm plantations , and hydroelectric projects that fragment the cotton @-@ top tamarin 's natural range .

The illegal pet trade and scientific research have also been cited as factors by the IUCN . While biomedical studies have recently limited their use of this species , illegal capture for the pet trade still plays a major role in endangering the cotton @-@ top . Before 1976 , when CITES listed the species under Appendix I banning all international trade , the cotton @-@ top tamarin was exported for use in biomedical research .

In captivity , the cotton @-@ top is highly prone to colitis , which is linked to an increased risk of a certain type of colon cancer . Up to 40 @,@ 000 individuals were caught and exported for research into those diseases , as well as Epstein @-@ Barr virus , for the benefit of humans . The species is now protected by international law . Although enough individuals are in captivity to sustain the species , it is still critically endangered in the wild .

The Proyecto Tití ( " Project Tamarin " ) was started in 1985 to provide information and support in conservation of the cotton @-@ top tamarin and its habitat in northern Colombia . Proyecto Tití 's programs combine field research , education , and community programs to spread awareness about this endangered species and encourage the public to participate in its protection . It now has partner status with the Wildlife Conservation Network .

In January 2015 , two captive cotton @-@ top tamarins at the Alexandria Zoological Park in Alexandria , Louisiana , died when a caretaker left them outside overnight in temperatures as low as 30 ° F. One other individual survived .