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A Review of Endemic Species in the Eastern Arc Afromontane Region: Importance, Inferences, and Conservation

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ABSTRACT

The Eastern Arc mountain region has been identified as one of the top 25 biodiversity "hotspots" worldwide, and contains a large proportion of endemic species. The endemic species are invaluable resources. This review paper will explore and discuss the possible theories behind the high rate of endemism. The importance of these endemics to local peoples and to the greater global community has been studied thoroughly, and these results are presented in further detail in this paper. The Eastern Arc is also facing many problems that are threatening the biodiversity and rare endemic species of this region. Human expansion into natural habitat, as well as deforestation and forest fragmentation are among the most pressing issues. The causes and impacts of these issues will be explored and suggestions for the protection and conservation of endemic species and biodiversity will be discussed.

INTRODUCTION

With many recent studies showing that the current global rates of biodiversity loss are cause for alarm, it is important to recognize regions in which biodiversity is especially high and under threat from human expansion. Moist tropical rainforests are the most important centers of biodiversity, as they cover only 7% of the land on earth, but contain nearly half of all known species (Newmark, 2002). The Eastern Arc Mountains and Forests (hereby referred to as "Eastern Arc"), located in the nations of Tanzania and Kenya, are recognized as one of the world's "biodiversity hotspots" (Myers *et al.*, 2000). All of these so-called "hotspots" have at least 1,500 endemic plant species, which are at risk for extinction because of deforestation and destructive human activities (Brooks, 2002). The Eastern Arc has long been known for its diversity of plant species and unusually high rates of both floral and faunal endemism (Burgess *et al*., 2002) and has recently been slated as one of the most threatened regions of global biodiversity significance, because extinction risk of both plant and animal species is intense and increasing (Burgess *et al*., 2007). In fact, this region has the highest known ratio of endemic plant and animal species worldwide, so it is of particular interest for conservation (Newmark, 2002).

Geography

The Eastern Arc Mountain range is defined as a chain of ancient Precambrian crystalline mountains composed of igneous and metamorphic rocks, which run from the Taita Hills in southern Kenya to the Udzungwa Mountains in south central Tanzania. Although the faults are ancient and the exact date of mountain uplift is unknown, it is estimated that the Eastern Arc was uplifted at least 30 million years ago (Burgess *et al*., 2007). Modern flora and fauna in Africa were only moderately affected by tectonic change. From the mid-Cretaceous to the mid-Tertiary there is no evidence of major tectonic disturbance in East Africa. Since the mid-Tertiary, there has been a northward drift of Africa, and the central African uplift caused the formation of an "arid corridor" isolation the eastern forests from the much larger central and western forest blocks (Fjeldsaå, 1997a)

The mountain range is not entirely continuous and there are wide gaps between different mountain clusters (nearly 100km in some adjacent blocks). The Eastern Arc Mountains range up to 2,635m in altitude with the highest point in the range being Kimhandu Peak in the Uluguru Mountain region, located in east-central Tanzania (Burgess, 2002).

Although Mount Kilimanjaro, the highest peak in all of Africa, borders the Eastern Arc Mountains, it is not considered part of the range, because it is quite young comparatively (only 2 million years old), and is a volcanic mountain as opposed to a block-faulted mountain. (Hemp, 2006). Burgess et al. (2007) has divided the Eastern Arc Mountains into thirteen distinct blocks, due to the disjointed geography of the mountains. The most studied and important of these regions are the Uluguru, Usambara (East and West), and Udzungwa regions in Tanzania because of their accessibility and large tracts of still intact primary forest.

CLIMATE

The climate of the region is an important part of why there is such high biodiversity in the Eastern Arc. The Eastern Arc is under direct climatic influence of the Indian Ocean to the east of the range, which provides significant rainfall to the forested mountains. The eastern faces of the Eastern Arc mountains receive > 3,000 mm of rain annually, with at least 100 mm of rain in every month, making the forests perhumid, an unusual occurrence in Africa, whereas the rest of the Eastern Arc receives between 1200 mm and 2000 mm annually (Burgess *et al.*, 2002). There is a bimodal monsoon pattern in the region, which brings significant rainfall from March to May, and shorter rains from October to December. Temperatures average around 18˚C, although temperature varies greatly with altitude. The hottest months of the year are December to March, and the coolest are from June to September (Newmark, 2002).

ENDEMISM

The degree of endemism in the Eastern Arc is extremely high, and possible explanations for this phenomenon have been presented and will be discussed further in this paper. Endemic species are of great importance for a host of different reasons. They are important on both global and local levels, as they provide unique genetic diversity for further study and provide local peoples with priceless services (Newmark, 2002). The Eastern Arc contains 1500 endemic plant and 121 endemic vertebrate species in 2000 km^2. This ratio for endemics per area is the highest of all biodiversity hotspots (Myers *et al.,* 2000). The rate at which endemics in the Eastern Arc and around the globe are becoming extinct is cause for alarm. There is, however, great awareness around the issue, and many groups have ongoing projects aimed at conserving the unique biodiversity in the Eastern Arc.

Causes Of Endemism in the Eastern Arc

The Eastern Arc has been the focus of many recent studies on both floral and faunal endemism. There are many theories that provide some insight into why the Eastern Arc houses such a large number of endemic species. It is not just that the endemic species are great in overall number, but they represent a surprisingly large proportion of the total population of organisms: around 10% of all species occurring in the Eastern Arc are endemic to the region (Iddi, 1998).

One of the most widely accepted theories for the high rates of endemism in the Eastern Arc is that the long duration of stable climate, estimated at 30 million years, has allowed plants and animals to thrive and evolve in the region without the threat of extinction due to climatic changes (Newmark, 2002). Climate studies have been conducted on the coasts of Tanzania using marine sediment cores to determine past climate patterns. It was found that the climate in the region was little influenced by the greater climatic shifts that occurred during the Pleistocene (Prell, 1980).

One theory related to the idea of climatic stability is the so-called "refuge theory". This theory suggests that paleoecologically stable areas would act as arks where local populations of specialized plants and animals survive periods of stress (mainly dry and cold periods), leading to divergent evolution of populations in the different refuges. The theory postulates that many extant plant and animal species originated in these refuge areas, which is backed up by the existence of adjacent areas with much lower rates of endemism, along with the fact that biogeographically relictual species exist in high concentrations in climatically stable regions (Fjeldsaå, 1997b). This suggests that the comparatively high species richness in refuge areas is due to the loss of diversity in areas affected by climatic cycles.

In a 1997 study, Fjeldsaå and Lovett determined that the Eastern Arc region had maintained a high climatic stability throughout the Pleistocene, and served as a refuge during the expansion of arid habitat during that time. They also found that the Eastern Arc has many relict species, whose closest relatives occur in Western Africa, Madagascar, and the Far East, which furthers the refuge theory (Fjeldsaå, 1997a). During the Miocene, the Pan African rainforest, which extended from eastern to western Africa, separated into two distinct forest regions, which is when relictualization of species in the Eastern Arc is thought to have started. After the disappearance of the Pan African rainforest, it is thought that parts of the forest were reconnected during brief wetter climatic regimes. There is evidence of species exchange in some Kenyan and western Tanzanian forests, but none in the Eastern Arc, which suggests that it has indeed remained isolated from West African forests for quite some time (Burgess *et al*., 1998). In relation to climatic stability, it is also suggested that the relative isolation of the Eastern Arc from similar habitat produces exceptionally high rates of endemism. Modern flora and fauna in Africa were only moderately affected by tectonic change. From the mid-Cretaceous to the mid-Tertiary there is no evidence of major tectonic disturbance in East Africa. Since the mid-Tertiary, there has been a northward drift of Africa, and the central African uplift caused the formation of an “arid corridor” isolation the eastern forests from the much larger central and western forest blocks (Fjeldsaå, 1997a). Additionally, the geography and topography of the montane region are thought to have contributed to the relative climatic stability of the region in times of globally intensive climatic changes, due to the closeness of the Indian Ocean and the higher altitude precipitation in the Eastern Arc (Burgess *et al*., 2007).

The long-term ecological stability associated with the Eastern Arc is thought to have promoted the persistence of forest species and reduced overall extinction rates. Species here have been evolving and accumulating for millions of years. DNA analysis has shown that a number of forest genera are genetically ancient. One study of forest birds in the Eastern Arc indicated that some species derive from lineages over 25 million years old. These lineages are older than in surrounding areas, and are in accordance with other such refuge areas like the Amazon basin (Fjeldsaå, 1997a). Also, a number of taxonomic groups of Eastern Arc endemics are often referred to as ‘primitive’, in the sense that they have a prolonged history of forest habitat. Furthering this view is the fact that the Eastern Arc has considerably more endemic species than that of the nearby volcanic mountains of Kilimanjaro and Meru, which only formed relatively recently (2 million years ago). Additionally, these volcanic mountains do not share the relict biogeographical connections with Madagascar, Asia, and Western Africa that the Eastern Arc does (Burgess *et al*., 2007).

Besides the climatic stability of the region, other explanations have been suggested that offer insight into the high endemism in the Eastern Arc. One such explanation is that the Eastern Arc has had elevated rates of *in situ* speciation. For species of the genus *Saintpaulia* (commonly known as the African Violet), studies in the Usambara Mountain region show recent diversification of local populations, implying high rates of speciation (Kolehmainen & Korpelainen, 2008). Molecular studies have also shown that in some areas of the Eastern Arc there is a considerable amount of gene flow between populations in different tracts of forest, as well as gene flow breaks, which correspond to physical barriers. Such barriers include rocky escarpments and forest gaps (Burgess *et al*., 2007). The combination of both genetically ancient and newly evolved species in the same area indicates that the Eastern Arc is both a center of ongoing evolution, as well as a museum of ancient species (Burgess, 1998).

Importance of Endemic Species

We know that the Eastern Arc has one of the highest rates of endemism in the world, but why are these endemic species important? Endemic species are of both local and global importance. They increase the amount of genetic diversity and offer insight into biogeographical questions, such as where certain species originated and how distribution patterns have changed over time. The humans and other species in the Eastern Arc also rely on the biodiversity for basic needs and survival, and if biodiversity in the region were to significantly drop, there would be a lack of traditional and dependable resources for local peoples.

Local people in third world regions rely on their surrounding environment to provide resources necessary for sustaining life. It is no different in the Eastern Arc. Traditional healers provide the most common form of medical attention in Tanzania, and they use many plant parts from the surrounding regions in their remedies. These plants have been found to cure a variety of illnesses and have also been used in western pharmaceutical studies. Such plants include the tree species *Maesa lanceolata*, which contains an antibiotic and is used locally to prevent cholera and treat intestinal parasites (Newmark, 2002). The medicinal value of these plants are important not only to locals, but to the entire medical community, as the ongoing search for remedies and preventative treatments for disease continues.

In addition to plants being used as medical remedies, they also provide a reliable food source. Eastern Arc plants are heavily incorporated into the diets of village residents. Green leafy plants and mushrooms are often included in meals, along with the staple of starch-rich maize or stewed bananas. The leafy greens add much of the nutritional value to the diet of local people, as meat is not always readily available. The plants that are most commonly used in stews are high in protein, iron, calcium, and zinc, in addition to other nutrients. Some plants used for stewing include restricted range endemics like *Discoreophyllum volkensii*, found in the Usambara region of the Eastern

Arc (Vainio-Mattila. , 2000). Hunting in forested areas is also a common practice in these mountains, and endemics such as Abbot's Duiker, a small forest dwelling antelope, are among the species hunted in the Eastern Arc. Locals also gather firewood, rope, and building materials from the invaluable forests that surround villages (Kingdon, 1989).

There is also high economic value in the Eastern Arc in terms of endemic species. At least fourteen species of coffee plant are endemic to the Eastern Arc, and these species have a high economic value as a cash crop for export (Rodgers, 1982). Furthermore, the Eastern Arc has many species that are exported and cultivated by horticulturists worldwide. Perhaps the most famous of these species is the African Violet, of which there are many species, nearly all of which are endemic to the Eastern Arc (Newmark, 2002).

Perhaps one of the most overlooked values of endemic species, and specifically those in the Eastern Arc, is that they provide a great amount of data for further study on evolutionary history. Many ancient lineages in plants, birds, and primates have been traced back to the Eastern Arc. There are ongoing studies in DNA analysis and comparison of Eastern Arc lineages to those in other parts of the world. Further studies could help unearth biogeographical questions about range, origin, and evolution of species. Many see the Eastern Arc as one of the most important remaining evolutionary centers, due to the high amount of relictual taxa (Fjeldsaå, 1997a).

Range and Dispersal of Eastern Arc Endemics

Endemic plant species in the Eastern Arc have been largely unable to move beyond their current range for a number of reasons. The environment of long climatic and geological stability, as well as the isolation from other similar habitats has made the endemics in this region vulnerable to changing environmental conditions. Most endemic plants are specialists, meaning that they inhabit a very particular area and require a specific set of ecological conditions in order to flourish. It should be noted that endemic species in the Eastern Arc occur throughout the elevational, latitudinal and moisture gradients, but most plants are restricted to certain altitudinal or temperature ranges or require a certain amount of rainfall or sunlight. Due to the specificity of habitat requirements for these endemic plants, they are unable to survive and expand into areas that do not meet their ecological needs (Lovett, 1998).

There has been some dispersal of plants that originated in the Eastern Arc to nearby volcanic mountains like Meru and Kilimanjaro. These mountains have only recently been able to recruit plant species from the Eastern Arc by providing a habitat similar to that of the Pare region and Taita Hills of the Eastern Arc. Some of these dispersal events are thought to have occurred through human mediation, as humans have inhabited the foothills of Kilimanjaro for at least the past 2000 years (Hemp, 2006).

The story is largely the same for endemic animal species. 70% of endemic birds and all endemic mammals and amphibians are confined to dense primary forest habitat. A 1997 study showed that organisms living in areas of eco-climatic stability were more likely to be adversely affected by habitat disturbance. It is hypothesized that organisms that evolved in an unstable area are more robust, in that they are more adaptable to a changing environment (Danielsen, 1997). Most (over 60%) endemic birds live in areas above 1,200 m altitude, and they do not move to other altitudinal levels often, if ever. Forest litter arthropods show a high single-mountain endemism throughout the Eastern Arc. For example, 80% of endemic *linyphiid* spiders are classified as single-site endemics (Scharff, 1993). There are some strange distribution patterns in the Eastern Arc as well. It has been noted, in vertebrate species especially, that there are some areas where endemics are extremely abundant and others where they are seemingly absent (Burgess *et al*., 1998). Frontier-Tanzania conducted a five-year survey of endemics in 1995 using a standardized survey program, and found such disjunct distributions in vertebrate species such as the rodent *Beamys hindei* and the toad *Mertensophryne micranotis*. This suggests that although there may have been uneven collecting intensity in the studied forests, the overall pattern of disjunction and site-specific endemism seems to be a real phenomenon (FitzGibbon *et al.,* 1995). Further study is warranted in order to provide further evidence for these patterns.

Problems Facing Endemics

Biodiversity is under increasing threat worldwide as human populations increase and natural habitat areas are destroyed. Endemic species are inherently at greater risk for extinction than other species because of the strictly limited range that they have. Rarity and small population size, characteristics generally associated with endemic species, have been shown empirically to be an important predictor of extinction (Diamond, 1984). In the Eastern Arc, endemic species are currently under increasing pressure to survive from the practices of deforestation and human expansion into undisturbed forests, which contribute to habitat loss.

Forest Fragmentation

One problem that is plaguing the Eastern Arc in increasing amounts is forest fragmentation. Forest fragmentation occurs when continuous forest habitat is broken up into smaller patches because of deforestation due to logging or development (usually for the sake of agriculture). This is problematic because it changes the landscape that organisms have evolved in and adapted to. Instead of a large continuous forest, the Eastern Arc is now largely made up of a mosaic of forest habitats. This increases the amount of edge habitat and decreases the amount of dense interior forest habitat, which many endemics require (Newmark, 1998). Non-endemic generalist species are more apt to survive in areas that have been disturbed or fragmented, and can push endemic species out by taking over their niche. These generalist species tend to have ecological characteristics that make them better competitors in disturbed environments, because they can survive under a wider range of ecological conditions than restricted range endemics (Burgess *et al*., 2002).

Forest fragmentation can occur for a variety of reasons. Many communities in Eastern Africa practice small-scale agriculture; in villages in the Eastern Arc, this can lead to significant fragmentation of natural forest. Agricultural fields are usually mono-cropped, and all other species are removed. Commercial growth of coffee, tea, and cardamom has also increased dramatically in the past fifty years. Cardamom, which was introduced into Tanzania in the 1960s, is particularly problematic in the way that it is cultivated: forest understory is cleared and replaced by cardamom crops. After five to seven years, yields of the crop will decline and the field will be abandoned, leaving behind degraded soil and fragmented forest with no hope for becoming primary forest again (Newmark, 2002).

Not only does this direct deforestation harm endemics, but it also creates a zone where no endemics can live, causing problems for dispersal and decreasing the range of endemics even more. Communities in the Eastern Arc also clear land for homes, and build roads through the forest in order to facilitate contact and trade with others nearby. Commercial logging and large-scale agriculture have also taken their toll on forest systems in the Eastern Arc. The practice of logging removes large trees, many of which are endemic in the Eastern Arc, and it also removes the habitat of other species that depend on the trees. Endemic invertebrates are particularly vulnerable to deforestation, as they tend to specialize and become restricted to smaller ranges. (Burgess, 1998).

Forest fragmentation can have other adverse effects on forest communities that might not be as noticeable on the surface. Fragmentation can affect the integrity of entire forest communities. Two recent studies looked at how forest fragmentation affects mutualism between endemic tree species and animal seed dispersers. In tropical habitats, nearly 90% percent of tree species produce fruit of some kind, which is adapted for dispersal by animals. When forest becomes fragmented, animal seed dispersers have less of a presence and trees have difficulty recruiting seedlings. This hypothesis was tested in forest fragments in the East Usambara Mountains, looking at the dispersal of seeds from the endemic *Leptonychia* tree. The 2003 study found that the number of seed dispersing birds that visited fruit bearing trees was nearly three times higher in continuous forest than it was in forest fragments. In addition, it was found that six fewer seed dispersing species of bird were present in fragments than in continuous forest. Because of these factors, many seeds were not removed from the trees occurring in fragments at all. The study did take into account that some seed dispersing bird species were more effective than others, meaning that some dispersers resulted in more seedling recruitment than others. The study found that removal of seeds by the most effective dispersers was greatly reduced in forest fragments, and that this reduction was not compensated for by other bird species. The researchers noted two possible effects that lower seed removal could have on this endemic tree. Seeds that are not removed generally have higher mortality rates under the parent tree. In some species, however, inability to disperse seeds away from the parent may result in clumping of species. To quantify this, the study noted that there were 58% fewer juvenile plants per area in forest fragments than there were in continuous forest (Cordeiro, 2003).

Another study focused on the difference between endemics and non-endemics, related to the phenomenon of mutualism severance between trees and dispersers. It found that the proportion of seedling and juvenile endemic species were lower than those of non-endemics in forest fragments. This suggests that endemic species have a harder time adapting to loss of animal dispersers than non-endemics. In fact, the study showed the recruiting of endemic animal-dispersed trees was forty times higher in continuous forest than it was in small fragments. The study also made interesting findings about the difference between animal-dispersed and gravity or wind-dispersed plant species. It found that gravity or wind-dispersed organisms were faring just as well in fragmented forests as they were in continuous forests. This finding provides further evidence to the theory that animal dispersed endemic species in particular are adversely affected by forest fragmentation (Cordeiro & Howe, 2001).

Introduced Species

In addition to fragmentation of forests, endemic plant species also have the problem of introduced exotic species, which compete with endemics and other native species for resources. Most of these species were introduced by humans as food crops, ornamentals, or for use as timber. A study by Binggeli and Hamilton (1993) in the East Usambara region of the Eastern Arc showed that at least 48 exotic plant species have become naturalized in the region. Most of these species do not pose a direct threat to native species and actually increase the biodiversity of the Eastern Arc. There are some species, however, which have been shown to be problematic. One such species that has been shown to be particularly problematic is the tree *Maesopsis eminii*, which was introduced to the Eastern Arc nearly a century ago from Central and West Africa for use as timber and fuelwood. Since the introduction of *Maesopsis*, it has spread rapidly along forest edges and in gap areas. *Maesopsis* is a rapidly growing tree, whose seeds are widely dispersed by birds. This species has not been much of a problem in dense forest areas, as it requires a lot of sunlight to thrive. However, there have been a few instances of this tree occurring in dense forest, suggesting that they are widely dispersed by animals. Studies of this introduced tree have shown that it can dramatically change the ecological structure of the forest community. Though the names of specific species that were detrimentally affected by the presence of *Maesopsis* were not included in their results, Binggeli and Hamilton concluded that regeneration of native primary forest species was reduces, whereas non-native plant species increased. In the Kwamkoro Forest Reserve in the East Usambara Mountains, *Maesopsis* dominated stands contained only two shade tolerant primary forest species, but there was an increased abundance in other introduced species such as *Clidema hirta, Lantana camara,* and *Rubus rosifolius*. The root structure of *Maesopsis*, and the openness of the canopy under these trees also undermine the integrity of the forest. The openness of the canopy under *Maesopsis* is especially problematic, as it leads to soil erosion due to higher rates of rainfall directly hitting the forest floor. The soil in areas inhabited by *Maesopsis* is physically and chemically different from areas where natural vegetation dominates. The pH is higher in areas dominated by this introduced species (5.3 in

Maesopsis stands as opposed to 4.3 in native stands), and there is also less leaf litter in these areas that leads to a decrease in endemic plant and invertebrate species, which rely on the leaf litter as habitat. (Binggeli and Hamilton, 1993). Although this research provided results relating to one particular introduced species, it is hard to generalize trends relating to the effects of all such species without further study of additional organisms.

Climate Change

There are relatively few studies in the literature on how climate change might affect the environment in the Eastern Arc and how such changes might affect the biodiversity and endemic species in the area. The 'refuge' status of the Eastern Arc suggests that climate could remain relatively stable, even in the face of global climate change. If the climate has remained stable in past times of climatic stress, it should continue to remain relatively stable even if global climatic changes are noticed. Evidence indicates, however, that there have already been some small-scale local climatic changes in the past century. The climate in the Eastern Arc is slightly warmer and drier now than it was fifty years ago, which has been evidenced by changing altitudinal ranges of some endemic tree species. In addition, although there is a dearth of scientific evidence to back up these claims, stories from locals suggest that cloud cover has declined and also that rainfall (especially during the dry season) has declined (Newmark, 2001).

There have been hypotheses as to why the cloud cover has declined in recent years. It has been noted that the cloud base is usually just above the border between forest and farmland. This is because of the large amount of evapotranspiration that occurs in dense forest areas, and the lack of such transpirational processes that occur in farmland habitats. If land is further deforested, then the cloud band will continue to move further up the mountains. Deforestation, in effect, could have a dramatic impact on the cloud cover and local climate of the Eastern Arc (Burgess *et al*., 2001). There have also been studies in the Eastern Arc looking at the alteration of wind patterns as an effect of forest fragmentation. Saunders *et al.* (1991) found that the increased exposure of forest remnants to wind resulted in elevated physical damage to trees, increased evapotranspiration, and a decrease in humidity.

Forest fragmentation continues to be one of the central causes of biodiversity loss in the Eastern Arc. Much of the remaining forest is comprised of small forest patches. Many species, both plant and animal, are inhibited from crossing forest gaps, leading to a decrease in range, as well as a greater possibility of extinction. Although humans have inhabited the Eastern Arc for around two thousand years, in the last fifty years, forest loss and fragmentation have become dire problems. The effects of a drastic increase in population, such as logging and deforestation for agricultural practices, have already had visible adverse effects on the biodiversity of the Eastern Arc; a continuation of this trend could lead to catastrophic biodiversity loss.

ONGOING AND PROPOSED CONSERVATION STRATEGIES

Many species in the Eastern Arc are already at high risk for extinction, but there are many groups that are looking into the outcomes of forest loss and trying to prioritize which forest areas are most important for conservation. Ideally, all forest areas would be preserved, but due to increasing population pressures, some forest areas are doomed to deforestation in the near future. Extinction does occur naturally in all systems, but conservationists are concerned with reducing the impacts that humans have on overall rates of extinction, rather than focusing on individual extinction events. With help from scientists, governmental officials, local peoples, and non-governmental organizations, there is hope that these forests will be protected, and will continue to be thriving centers of both biodiversity and endemism. The conservation of the Eastern Arc forest needs to be considered a priority by the Tanzanian government, even in the midst of pressing social issues like extreme poverty and the need for education reform.

Comparisons of current forest area to estimated prehistoric forest cover in the Eastern Arc reveals that nearly 77% of forest area has been lost in the past 2,000 years. This forest cover was estimated by assuming that prehistoric forest cover started at the base of the mountains on the eastward side, and 400m up the mountain on the westward side, in order to account for the rain shadow effect. It was also assumed that the forests were continuous throughout their range. Current forest cover was estimated from digital aerial maps (Newmark, 1998). These losses have been largely attributed to the use of fire and the clearing of forests for agriculture, which have increased dramatically in the past century (Burgess *et al*., 1998). The need for action in this region has been recognized by many international organizations, such as Conservation International and the World Wildlife Fund. Recognition by these influential groups has put the Eastern Arc on the map as a priority for conservation. The Eastern Arc does, after all, have the highest density of strictly endemic species in the world. Raising awareness about the conditions of the region is an important first step to fixing the problem.

Current Conservation Efforts

The current efforts in the Eastern Arc regarding conservation are minimal and in need of more oversight and ideas about how to best preserve the remaining biodiversity. There are several government-protected reserves in the Eastern Arc, and these are essentially the only remaining large stretches of continuous forest in the entire mountain system. These reserves are vital, but they only do so much to help protect endemic species. There are also some forests that are protected in localized areas, and are of particular religious and cultural importance to some people. These conservation efforts are important, and should remain in place, but there is much more that can be done, and many factors that need to be looked at in order to assess the situation in the Eastern Arc (Burgess *et al*., 2001).

It should be mentioned that the overarching reason for the preservation of forests by the Tanzanian government was not initially to preserve the biodiversity of the areas, but rather to conserve important water catchments that provide the country with an abundant fresh water supply. The reserve in the Uluguru Mountains, for example, is imperative because it provides freshwater resources to Dar Es Salaam, Tanzania's largest city and home to over 2.5 million people and most of the country's industry (Burgess *et al.,* 2002). The plants in the forest reserves absorb large quantities of water from clouds, and then release it slowly into the waterway, allowing for a constant and reliable flow of fresh water. Although the forest is being preserved mainly for the benefit of people in the form of ecosystem services, and this is a huge asset to those that depend on the water catchment reserves, it must be realized that the preservation of biodiversity in the Eastern Arc also has other important benefits as well, which have been previously discussed in this paper (Iddi, 1998).

Conservation Parameters

There has been some disagreement among different groups as how best to prioritize certain areas for conservation. Some groups have looked at which areas have the most importance to humans (in terms of ecosystem services), and others have looked at which areas contain the most species, while still others have looked at which areas are the richest in endemic species. Each of these studies has made important contributions to the overall distribution of endemics, outlining which ones are most at risk and suggesting the most effective conservation strategies based on available information.

The threats to Eastern Arc species are increasing and solutions need to be put into place that reverse this trend. The Red Data Books compiled by the World Conservation Union measure the degree to which species in a given region are currently threatened with extinction. In 2008, 589 species across all taxa in Tanzania were listed as threatened. This amount of threatened species is second highest in all of Africa, with only Madagascar having slightly more threatened species. This number has increased continually since the Red Data Book results began being published in 1994, suggesting that threats to species are increasing, as well as that data regarding threatened species is becoming more accurate. The number of recent extinctions in the region is also likely to be a conservative estimate because of the time lag between deforestation and extinction (IUCN, 2008). A study in 2000 estimated that if there were a loss of 1000 km^2 of habitat in the Eastern Arc, that at least 120 plant and 10 vertebrate species would go extinct. Although a loss of this scale would be catastrophic, it is unlikely that such a sweeping loss would be allowed to happen. However, it is important to note that even small losses in habitat can lead to extinction events.

Dealing with conservation of endemics requires knowledge and planning that is specific to endemic species. Endemic species tend to be very fragile since they have such specific habitat requirements. Therefore, any level of disturbance could have an adverse effect on endemic species. Disturbed forests tend to have fewer restricted range species and are thought to be of lower biodiversity value than undisturbed forests. Considering these parameters, scientists and conservationists have come up with a number of areas that should be looked at as priority areas for conservation.

Suggestions for Conservation

First and foremost, it is suggested that the current conservation efforts remain in place, especially the forest reserves held by the Tanzanian government. Most endemic species are found in dense forest, and the reserves in place are some of the last large stretches of dense forest in the whole of the Eastern Arc. These reserves, however, only cover a fraction of the species and habitat areas that are under threat. Most of the reserves are at higher altitudes, which are areas that are under less threat from human encroachment anyways. The reserves are located in higher altitudes because of the water catchment properties of high altitudinal montane regions (Newmark, 1998). Since endemic species in the Eastern Arc occur throughout the elevational, latitudinal and moisture gradients, and all of these factors need to be assessed when looking at which areas need to be conserved. Additionally, some endemic species are only found in certain altitudinal bands, and if specific altitudinal levels are ignored, then the species makeup of the mountains will change as species are lost. Most of the forest loss in the Eastern Arc has occurred below 1000m altitudes. Conservation reserves should be set up in these areas before further losses occur in order to ensure that species with altitudinal ranges below 1000m are not disproportionately lost. Non-protected forest areas on public lands in the Eastern Arc should be given immediate protected area status in order to save the remaining biodiversity over a range of ecological and environmental conditions (Burgess *et al*, 2001).

Although dense forest has been found to be the primary habitat for endemic species, they are also found in grasslands, bogs, and rocky escarpments, which informs us that all areas are important for the conservation of biodiversity. Indeed, it was found that for East African plants, high species richness was associated with high geo-diversity (Taplin & Lovett, 2003). For the most effective conservation of endemics, this should be taken into account, and it should be a priority to consider all habitat types when creating plans for conservation.

Some conservationists suggest that small patches of forest should be given the most attention because they are under the greatest threat. It is true that some endemic species have been restricted to small forest areas, but most scientists suggest that in order to save the most species, resources should be concentrated on conserving large remaining forest patches, as opposed to making small patches a priority (Lovett, 1998).

Other possible solutions and conservation strategies have been suggested, but have yet to be implemented. With the high degree of forest fragmentation in the Eastern Arc being a leading cause of the threatened status of endemics, some suggest that wildlife corridors be used in order to possibly increase the habitat range for some species. Wildlife corridors are essentially narrow extensions of habitat that connect two similar areas in order to promote the mobility of species in each habitat area as well as improve gene flow in the area. Although the effectiveness of such corridors is widely scrutinized, it has been suggested as a means of mitigating the adverse effects of forest fragmentation by permitting organisms to move between isolated fragments. Since many species have trouble crossing gaps in the forest, the suggestion of corridors may well increase the range of some species. It is also thought that corridors can reduce the rate of extinction by allowing individuals to "rescue" or supplement declining populations. Corridors need to be designed carefully so that they can be effective in promoting interactions between different fragments. Width, length, and vegetation type, as well as the life histories of the animals using the corridors should be considered when designing corridors (Newmark, 2002).

In conjunction with the possibility of corridors and the conservation of existing habitat, there should ideally be an expansion of the current forest habitat cover in the Eastern Arc. Creating habitat could reverse some of the negative trends surrounding threatened species status in the Eastern Arc. The feasibility of this is disputed, however, due to the expanding population and need for resources and farmland. It should not be ruled out as a possibility and should be considered further, especially in areas where forest loss has been particularly devastating. (Burgess *et al*, 2001). However, officials should work with locals in order to restore forest without displacing people from their homes.

Another component of conservation efforts should be continual ecological monitoring, so that any changes in the region can be assessed and dealt with in a timely manner. Close monitoring of threatened species and indicator species, which can indicate the status of the overall health of the ecosystem, should be a priority. Further studies are warranted regarding the conservation Eastern Arc endemics, so that more information is available about how to prioritize certain areas for conservation and also about what methods of conservation are most effective.

CONCLUSION

The Eastern Arc is a truly unique area with a fascinating history and an abundance of endemic species. The importance of this region as a center of biodiversity has been recently recognized and studies about the phenomena of high endemism and the problems facing the region have subsequently been conducted. The Eastern Arc has been experiencing increasing pressure from human expansion and forest fragmentation, and many of the endemic species in the region are under threatened with extinction. There are some conservation efforts underway, but further conservation and other policies regarding habitat protection are vital to retaining the ecological integrity of the Eastern Arc. The literature surrounding the Eastern Arc is broad, and more specific studies should be conducted in order to further increase the knowledge surrounding this area. With the scientific community, along with international conservation organizations and local people recognizing the Eastern Arc for its unique characteristics, there is hope that the Eastern Arc will continue to be a center of biodiversity and endemism into the futu

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