Conservation Action Plan for Livingstone's Flying Fox

A Strategy for an Endangered Species, a Diverse Forest, and the Comorian People

Infant Livingstone's flying fox, photo by Elise F. Granek

Brent J. Sewall, Elise F. Granek, Mohamed F.E. Moutui, Will J. Trewhella, Paola F. Reason, Kathryn M. Rodríguez-Clark, Ishaka Saïd, J. Bryan Carroll, Will Masefield, Nassuri Toilibou, Michel Vély, Faissoili ben Mohadji, Anna T.C. Feistner, and Sue Wells

Action Comores antenne Anjouan; Associations Ulangas de Mohéli et d'Anjouan; Ministère de l'Agriculture, de la Pêche, de l'Industrie, de l'Artisanat, et de l'Environnement de l'Union des Comores; Ministère de la Coopération, de l'Equipement, et de l'Environnement d'Anjouan; Ministère du Développement Rural et de l'Environnement de Mohéli; and the Centre National de Documentation et de Recherche Scientifique

Action Comores - International, Bristol Zoo Gardens, Durrell Wildlife Conservation Trust, Global Environmental Facility, United Nations Development Programme, and the World Conservation Union (IUCN)

Executive Summary

Livingstone's flying fox, *Pteropus livingstonii*, one of the world's largest fruit bats, is endemic to two small islands of the Union of the Comoros in the western Indian Ocean. Its charismatic appearance and fascinating natural history have made it a cherished part of the Comorian national heritage, while its ecological role in seed dispersal and pollination are essential to the functioning of the Comorian montane rainforest ecosystem. This ecosystem is critical for the Comorian people, providing ecological services including erosion control, river maintenance, and the production of wood, fuel, food, fiber, and medicines. Livingstone's flying fox's persistence is closely linked to that of its rainforest habitat, which is an area of exceptional endemism and part of one of the world's most threatened biodiversity hotspots.

Livingstone's flying fox faces threats from increasing human encroachment on roost sites and deforestation of foraging habitat. Recent censuses have found only about 1,200 individuals in the wild, and the World Conservation Union (IUCN) has listed Livingstone's flying fox as Critically Endangered, indicating that conservation action is urgently needed.

Human pressures on Livingstone's flying fox habitat result primarily from increased land needs for agriculture, and use of wood for fuel and construction. Several other factors combine to exacerbate these pressures, including a high level of rural poverty, poor access to health care and education in rural areas, rapid population growth, a low level of understanding of the needs of the species, road building through native forests, and occasional catastrophic cyclones. The success of conservation efforts depends upon the involvement of local people, combined with coordination by the government at the island and national levels, leadership by Comorian environmental groups, and support from the international community.

This Conservation Action Plan has been developed *to conserve Livingstone's flying fox and its rainforest habitat, while also benefiting Comorian biodiversity and the Comorian people*. Some of the key objectives of the conservation strategy in this plan include protection of critical roosting and foraging habitat, forest management to maintain year-round availability of fruit and flower resources, development of school- and community-based environmental education programs, continuation of population monitoring and captive breeding programs, targeting of ecological research to benefit conservation, and collaboration with partner organizations to address broader underlying issues. Each of these seven programs can stand alone, but each also overlaps with and complements the other programs. Capacity-development of Comorian personnel and timely evaluation of program activities are also key elements of the plan, and have been integrated into each program. This *Conservation Action Plan* is part of a broader effort to establish a framework for rural poverty alleviation, sustainable development, and conservation of biodiversity in the Union of the Comoros.

Sommaire Exécutif[1]

La Roussette de Livingstone, *Pteropus livingstonii*, une des chauves-souris les plus grandes du monde, est endémique à deux petites îles de l'Union des Comores, dans la partie occidentale de l'Océan Indien. Son apparence charismatique et son histoire naturelle fascinante en font un patrimoine national des Comores ; tandis que son rôle écologique, dans la dispersion des graines et la pollinisation, est essentiel au fonctionnement de l'écosystème de la forêt tropicale comorienne. Cet écosystème est fondamental à la vie du peuple comorien, dans la mesure où il contribue à la fourniture de services écologiques, à travers notamment le contrôle de l'érosion, l'entretien des bassins hydrographiques, et la production de combustibles, de bois de construction, de ressources alimentaires, de fibre, et de substances médicinales. La persistance de la Roussette de Livingstone est liée fortement à celui de son habitat de forêt tropicale comorienne, qui constitue un « hotspot de biodiversité » où la diversité des espèces est exceptionnellement élevée et extrêmement menacée par rapport aux autres régions du monde.

[1] Une version francaise de ce document est disponible aussi.

La Roussette de Livingstone est menacée par suite de l'activité humaine accrue près des dortoirs et du fait du déboisement des zones d'habitat de cette roussette. Des recensements récents ont révélé la présence de 1.200 individus seulement à l'état sauvage, et l'Union Mondiale pour la Conservation de la Nature (UICN) a classé la Roussette de Livingstone parmi les espèces menacées et en danger critique qui nécessitent donc des mesures urgentes de sauvegarde.

La pression humaine sur l'habitat de la Roussette de Livingstone résulte essentiellement des besoins en terres pour la pratique de l'agriculture, et en bois de chauffe aux fins de combustibles et pour la construction. La conjugaison de plusieurs facteurs contribue également à exacerber cette pression anthropique, au nombre desquels, il faut citer la grande pauvreté en milieu rural, l'accès inadéquat aux soins de santé et à l'éducation, la croissance démographique rapide, la faible connaissance des besoins de la roussette, la construction de routes à travers la forêt, ainsi que les catastrophes naturelles qui interviennent occasionnellement du fait des cyclones. Le succès des efforts de conservation dépend de l'implication des communautés locales, sous-tendus par la coordination du gouvernement au niveau des îles et au plan national, et par la direction des groupes environnementaux comoriens, ainsi que par l'appui de la communauté internationale.

Ce Plan d'Action vise à *conserver la Roussette de Livingstone et de son habitat forestier, tout en profitant également à la biodiversité et au peuple comoriens*. Quelques objectifs clefs dans la stratégie de conservation dans ce plan sont la protection des zones d'habitat et d'alimentation de la Roussette ; la gestion des aires protégées pour sauvegarder la pollinisation des fleurs et la production de fruits tout au long de l'année, en tant que ressources alimentaires de la Roussette de Livingstone ; l'éducation environnementale au niveaux scolaire et communautaire ; la poursuite des efforts de surveillance des habitats et de l'élevage en captivité ; les travaux de recherche écologique menés au profit de la conservation ; et la collaboration avec des organisations partenaires pour les solutions fondamentales. Chacun de ces sept axes programmatiques, tout en étant autonome, présente une complémentarité avec les éléments des autres programmes. Le renforcement des capacités du personnel comorien et l'évaluation opportune constituent des autres objectifs, qui sont intégrés dans chacun de ces programmes. Ce *Plan d'Action* s'inscrit dans le contexte d'une initiative globale visant à mettre en place, un cadre d'amélioration de la pauvreté rurale, le développement durable, et la conservation de la biodiversité dans l'Union des Comores.

Acknowledgments

This *Conservation Action Plan for Livingstone's Flying Fox*, or *Plan d'Action pour la Conservation des Roussettes de Livingstone* (PAC) is a national and international conservation plan for a fruit bat species endemic to the Union of the Comoros, western Indian Ocean. The PAC was developed *to conserve Livingstone's flying fox and its rainforest habitat, while also benefiting Comorian biodiversity and the Comorian people*. The conservation strategy outlined here is the culmination of extensive consultation and collaboration with many individuals and groups beginning in early 2000. This plan is notable for its in-depth collaboration, integrating extensive advice and data from a wide variety of sources. It began with a wide-ranging consultation with local people, beginning with a set of meetings involving more than 3000 villagers in nearly 30 villages on the islands of Moheli and Anjouan. From this foundation, international researchers, the Comorian island and national governments, and Comorian and international conservation organizations formulated a set of proposals within the framework of the global conservation plan for Old World fruit bats (Mickleburgh *et al.* 1992), the Comoros National Strategy and Action Plan for the Conservation of Biological Diversity (Roby & Dossar 2000), existing national legislation, and the social and economic realities experienced by local people. An interdisciplinary set of scientists provided the most up-to-date relevant scientific information available, and presented it in an easily understandable format.

The PAC was developed through a close collaboration between the Comorian non-governmental organization Action Comores antenne Anjouan, villagers from throughout the islands of Anjouan and Moheli, a range of international scientists, national and international conservation organizations, the island governments of Anjouan and Moheli, the Comorian national government, and the Projet Conservation de la Biodiversité et Développement Durable aux Comores. This organization, hereafter called Projet Biodiversité, was run from 1998-2004 by the Union of the Comoros' Ministère de la Production et de l'Environnement, with technical assistance from the World Conservation Union's (IUCN) East Africa Regional Office and financing from the Global Environmental Facility, the United Nations Development Program (UNDP), and the government of the Union of the Comoros.

The PAC was then approved and feedback was provided by village representatives, conservation groups, and the Comorian government during the *Workshop to Reflect on the Conservation Action Plan for Livingstone's Flying Fox* on the 12th and 13th of November, 2004. Implementation of the conservation plan was organized during the *Workshop for the Implementation of the Conservation Action Plan for Livingstone's Flying Fox* from the 22nd to the 24th of March, 2006.

We would like to extend our sincere appreciation to all those who contributed directly or indirectly to the development of this plan. We would also like to acknowledge the national and international conservation organizations that contributed significant resources and provided logistical support, including, in addition to those mentioned above, Projet Biodiversité – Mohéli office, the Ulanga groups and Federation, IUCN – East Africa Regional Office, Action Comores-International, University of Minnesota Conservation Biology Graduate Program, Bat Conservation International, Dayton-Wilkie Natural History Fund of the Bell Museum of Natural History, Office of International Programs of the University of Minnesota, MacArthur Program of the University of Minnesota, Durrell Wildlife Conservation Trust, Conservation International, Bristol Zoo Gardens, University of California – Davis, American Society of Mammalogists, and the Centre National pour la Recherche et la Documentation Scientifique aux Comores (CNDRS). We would like to acknowledge the contributions of the numerous scientists who contributed comments and helpful advice, including Amy Freestone, Joseph Hawes, Joanna Durbin, Neil Maddison, Harison Randiranasolo, John Fa, John Hartley, Nancy Drilling, Jennifer Talbot, Anthony Starfield, Diane Larson, and Dirk Van Vuren.

We also greatly appreciate the advice, feedback, and encouragement provided by the diverse participants of the validation and implementation workshops. Our sincere thanks go to the participants of the *Workshop to Reflect on the Conservation Action Plan for Livingstone's Flying Fox* from the 12th to 13th of November, 2004, which included Mohamed Soilih, Sakina M'ze, Nadhufou Fadhula, Abdouroihamane Loutfi, Abdou Ahmed Toimi, Hamid Ahmed, Saïd Azilani Musbahou,

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We would particularly like to acknowledge the residents of the 30 villages on Anjouan and Moheli who participated enthusiastically in interactive town meetings to discuss the future of Livingstone's flying fox and sustainable development in the Comoros Islands during 2000, 2001, and 2003. Finally, I would particularly like to offer a personal word of thanks to all the other authors of the PAC, who volunteered hundreds of hours of effort over the course of several years to ensure the success of this plan.

The close cooperation by all of these parties and the comprehensive nature of this plan demonstrate the impressive commitment of the government and the people of the Union of the Comoros and their national and international partners both to the conservation of Livingstone's flying fox and its forest habitat, and to sustainable development for rural Comorians.

Brent Sewall
Coordinator
Conservation Action Plan for Livingstone's Flying Fox
April 3, 2007

Forewords

Excerpt from a statement by the Minister of Cooperation, Equipment, and the Environment of the Autonomous Island of Anjouan, delivered during the *Workshop for the Implementation of the Conservation Action Plan for Livingstone's Flying Fox*

Welcome to this workshop, which aims to implement the *Conservation Action Plan for Livingstone's Flying Fox* and its habitat, and which, in the name of the government of the Autonomous Island of Anjouan, I have the honor of proceeding to open. I firmly and solemnly affirm that our government commits itself firmly to this effort, and accords conservation actions for Comorian floral and faunal diversity a special importance…

As you know, Livingstone's flying fox is extremely important for the future of our rainforests due to its role in maintaining ecological balance and conservation of our waters and fertile soils. By preventing erosion, it even protects our coral reefs and fishing zones against pollution. Deforestation has caused a rapid retreat of the primary forest, and this irrational and anarchic activity threatens not only the fruit bats, but also the entire flora and fauna of a country whose high levels of diversity and endemicity are recognized by international scientific institutions…

However, until now the absence of a shared vision between Ulanga associations and the direct and indirect consumers of natural resources has hampered conservation efforts for all conservation institutions. For this reason, we greatly appreciate the joint efforts of our government and Action Comores and its national and international partners who, since the 1990's have not ceased to work for the noble cause of the conservation of Livingstone's flying fox. Much work has been done for this goal – a monitoring program, scientific research, and a captive breeding program by Durrell and Bristol Zoo in England, to name but a few.

So that all these actions could be coordinated, a *Conservation Action Plan for Livingstone's Flying Fox* has been developed in collaboration with a large number of local, national, and international partners, including Action Comores Anjouan, the government, and foreign researchers.

The mission of the plan is to conserve Livingstone's flying fox and its habitat in the Comoros Islands, while benefiting Comorian biodiversity and the Comorian people. Some key aims of the plan are to: protect roost and foraging sites that are critical for the species; manage protected areas for a permanent availability of fruit and flower resources for the bat; develop community- and school-based environmental education programs; continue ongoing roost monitoring and captive breeding programs; target ecological research to benefit conservation; and build the capacity of local people…

I want to convey that the government is cognizant that the Livingstone bat is critically endangered and is an important component of our rich rainforest. We are aware that our forests are disappearing. The government is very concerned and is struggling to reverse the process…
The government has hope that a creative, participatory approach where we work together with local communities to develop income alternatives that also save the forest is a more efficient method to quickly reduce poverty. I can promise you the cooperation and support of the government as we jointly develop long-term conservation plans…

This strategy has been conceived through a participative approach involving all actors. Public authorities, from local to national, and environmental non-governmental organizations will each have a role to play in assuring the success of these efforts. I encourage everyone and request of everyone to engage in this effort over the long-term.

I would like finish in reaffirming the will and the engagement of the government of the Autonomous Island of Anjouan led by his excellence the President Mohamed Bacar to support the Convention targeting the protection of biological diversity, and in particular the *Conservation Action Plan for Livingstone's Flying Fox*.

Mr. Abou Moussa
Minister of Cooperation, Equipment, and Environment of the Autonomous Island of Anjouan
Mirontsy, Anjouan, the 22nd of March, 2006

Excerpt of a statement by the representative of National Directorate of the Environment, delivered during the *Workshop for the Implementation of the Conservation Action Plan for Livingstone's Flying Fox*

I have the distinct honor to represent here the National Directorate of the Environment in this important meeting dedicated to the implementation of the *Conservation Action Plan for Livingstone's Flying Fox* and for its habitat. In the name of the National Directorate for the Environment, I would like to thank for their collaboration the numerous local, national, and international partners who have contributed to the development of this *Action Plan*, whose mission is to conserve Livingstone's flying fox and its habitat in the Comoros Islands, while benefiting Comorian biodiversity and the Comorian people.

Conservation efforts for this endemic species are part of a comprehensive national biodiversity conservation effort, as expressed in the *Diagnostic on the Environment*, the *National Policy*, the *Environmental Action Plan*, the framework law, and the protected species policy statement. Through the *Biodiversity and Sustainable Development in the Comoros Project*, the government has initiated a national network of protected areas. All of these efforts reflect the full engagement of our country in related international conventions. By associating diverse partners, this workshop is living proof of the participative approach initiated by the *National Environmental Policy*.

Mr. Ismaël Bachirou
Representative of the National Directorate of the Environment
Mirontsy, Anjouan, 22nd of March, 2006

Excerpt from a statement by the representative of the Minister of Rural Development and the Environment of the Autonomous Island of Moheli, delivered during the *Workshop for the Implementation of the Conservation Action Plan for Livingstone's Flying Fox*

In the name of the governments of the Autonomous Islands of Moheli and Anjouan and in my capacity as Minister of Rural Development and the Environment, I take this opportunity to affirm to the participants and partners our firm commitment to protect the environment, and in particular species threatened with extinction.

Our holding of this *Workshop on the Implementation of the Conservation Action Plan for Livingstone's Flying Fox and its Habitat* on the Autonomous Island of Anjouan is evidence of this will, as was highlighted by my colleague in his opening statement.

While it is true that our country is in a difficult political and economic situation, the cause of environmental protection calls us all to unite to protect our ambassadors of Comorian biodiversity: the sea turtle and Livingstone's flying fox. After the *Conservation Action Plan for the Sea Turtle*, we have focused on the implementation of the *Conservation Action Plan for Livingstone's Flying Fox* with the assistance of international experts of Durrell Wildlife, Bristol, Conservation International, and the Coordinator of the *Conservation Action Plan*, joining us from the United States, with the objective of permitting all participants to contribute on behalf of their institutions and to understand the role that they can play in the execution of the plan.

For the governments of the islands, we will bring our unconditional support, using the participative approach – an indispensable tool for sustainable development. I call on all participants of this workshop to work together to ensure the proper execution of the *Conservation Action Plan for Livingstone's Flying Fox*.

Mr. Faissoili ben Mohadji
Minister of Production and the Environment
Mirontsy, Anjouan, 26th of March, 2006

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Part I. Introduction

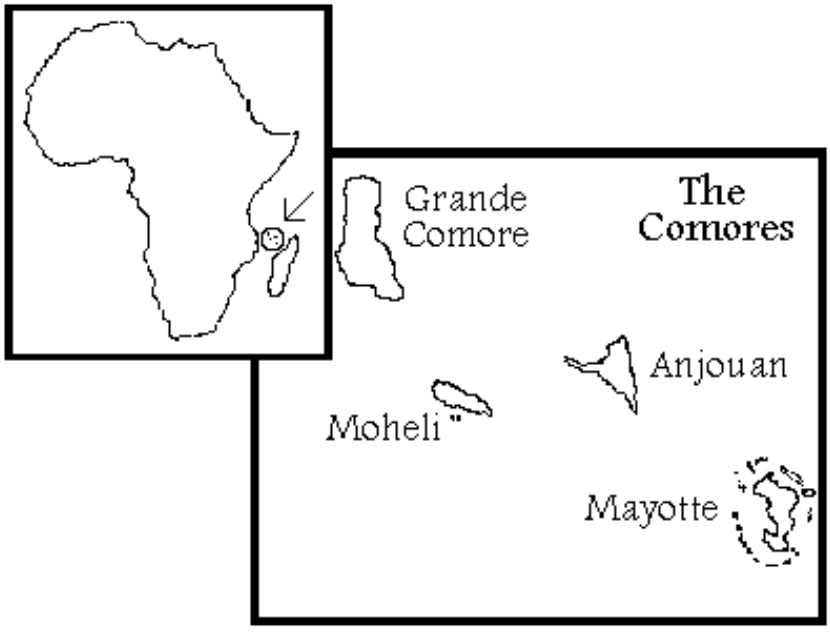
Livingtone's flying fox

Livingstone's flying fox, *Pteropus livingstonii* (also known as Livingstone's fruit bat or the Comoros black flying fox) is a giant fruit bat found on only two small islands, Anjouan and Moheli. These islands are part of the Union of the Comoros, a small developing island nation located between Madagascar and Mozambique in the western Indian Ocean (Figure 1). Its black color, rounded ears, and enormous 1.4 meter wingspan distinguish it from the two other Comorian fruit bats. Livingstone's flying fox's charismatic appearance and interesting natural history make the bat an important part of the Comorian national heritage, while its ecological role in seed dispersal and pollination may play a key role in the functioning of the Comorian montane rainforest ecosystem (Fujita & Tuttle 1991). This ecosystem provides ecological services including erosion control, river maintenance, and the production of wood, fuel, food, and medicines to the Comorian people, while harboring a diversity of endemic species.

Comorian biodiversity

The Comoros Islands (Figure 1) are a site of exceptional endemism, containing a high concentration of endemic plants, vertebrates, and other species (Caldecott *et al.* 1996, Myers *et al*. 2000). Recognition of the high concentration of endemism and biodiversity has lead to designation of the Comoros Islands (along with the other islands of the Madagascar / West Indian Ocean island region) as one of the Earth's "biodiversity hotspots" – land areas throughout the world "where exceptional concentrations of endemic species are undergoing exceptional loss of habitat" (Mittermeier *et al*. 1998, Myers *et al.* 2000). Based upon concentrations of biodiversity and overall level of threat to biodiversity, the region is considered to be among the 'hottest' of all the biodiversity hotspots (Myers *et al*. 2000, Brooks *et al*. 2002). This status makes the Comoros Islands of exceptional global priority for conservation (Myers *et al*. 2000, Brooks *et al*. 2002), yet relatively little conservation action has been undertaken there.

Figure 1. The Comoros Islands



Threats to Livingstone's flying fox

The largest threat to Livingstone's flying fox appears to be loss of its forest habitat. Livingstone's flying fox roosts and forages on two islands, primarily in native rain and cloud forest habitat (Trewhella *et al*. 1998, Granek 2002, Sewall 2002) which is highly threatened.

Deforestation in the Union of the Comoros is due primarily to conversion of forest to agricultural land and use of wood for cooking (Weightman 1987). In some localities on Anjouan, wood use for fuel by distilleries has resulted in large-scale deforestation, and selective cutting of trees for construction or sale of boards is an important cause of loss of many hardwood canopy tree species (M. Moutui, I. Saïd, B. Sewall, pers. obs.). The recent arrival of chainsaws on Anjouan, if their use in forests is not stopped, will without a doubt speed up this process considerably. Needs for land, fuelwood, and construction wood have increased as the human population has steadily increased in size. Human impacts begin near towns, fields, or roads, and over time extend progressively further up the mountainsides into remaining forest. Loss of forest in the future may be exacerbated by plans that have been proposed for road construction through remaining tracts of native forest on Moheli and Anjouan.

The combined extent of native and underplanted forest on the islands of Moheli and Anjouan was 117.4 km^2 as of 1987 (Agrar und Hydrotecknik GMBH 1987, Trewhella *et al*. 1998), and forest has disappeared rapidly since then. Nearly 30% of Moheli's native forest disappeared between 1983 and 1996 (Moulaert, 1998). Between 1990 and 1995, the Union of the Comoros experienced an annual deforestation rate of 5.8 %, the fourth-highest rate of any country (Jolly & Fukuda-Parr 2000). At these rates, it is likely that a cumulative total for both islands of less than 50 km^2 of native and underplanted forest remains, and deforestation continues.

This deforestation is especially troubling since vertebrate frugivores in tropical forests are especially susceptible to habitat loss, since they require large foraging areas to search for seasonally fruiting food resources (Terborgh & Winter 1980). Such deforestation is also leading to increasing human encroachment on roost and foraging sites (I. Saïd, E. Granek, B. Sewall, pers. obs.).

The occasional cyclones that hit the Union of the Comoros are also likely to pose an important threat to Livingtone's flying fox. Such cyclones have in the past resulted in extensive damage to rainforest habitat (Benson 1960). The effects of cyclones may be exacerbated since forest fragmentation and loss may make roost trees more susceptible to destruction from wind damage and other natural disturbances (Robertson 1992, Lewis 1998, Laurance *et al*. 2002). For example, the cyclone Cleine II in 1979 apparently resulted in a loss of half the population of the Rodrigues bat population on Rodrigues Island (Mungroo 1979, cited in Carroll 1988).

No hunting of Livingstone's flying fox is known to occur, and hunting is not considered to be a significant threat to the species currently. However, it is important to monitor this situation, since occasional hunting of the Comoros yellow-headed flying fox for food, and some sport hunting of the Comoros rousette have been observed in the Union of the Comoros (Sewall *et al.* 2003, Trewhella *et al*. 2005). These are currently rare events, but since flying foxes have a low reproductive rate, hunting is a particularly large problem for the genus (Pierson & Rainey 1992), and hunting has devastated flying fox populations in other areas of the world (Mickelburgh *et al*. 1992, MacKinnon *et al*. 2000).

Flying fox species (genus *Pteropus*) are threatened across the Old World tropics and subtropics. Of the 59 species in the genus (Nowak 1997), 7 are Critically Endangered, 3 are Endangered, and a further 16 are Vulnerable (Hilton-Taylor 2000). Already, 5 flying fox species have gone extinct (Hilton-Taylor 2000), of which 2 were previously common western Indian Ocean species (Louette 1999).

Recent censuses have found only 1,200 individuals in the wild (Action Comores antenne Anjouan and Action Comores – International, unpublished data). Because of their small area of occupancy, habitat loss, small population size, and a suspected decline in population, Livingstone's flying fox is listed as Critically Endangered, indicating that conservation action for its protection is urgently needed (Hilton-Taylor 2000).

Geographic and social context[2]

The islands of the Comoros archipelago lie 300 km from both Madagascar and Mozambique in the western Indian Ocean (Figure 1). The three islands of the Union of the Comoros (or Union des Comores, known until the end of 2001 as the République Fédérale Islamique des Comores) are Grande Comore (Ngazidja in Comorian), Anjouan (Nzwani), and Moheli (Mwali). The fourth island

[2] Adapted from Sewall 2002.

of the archipelago, Mayotte (Mahore), is a *collectivité départementale* of France, and it is also claimed by the Union of the Comoros.

Grande Comore, Anjouan, and Moheli are home to a high-density population of more than 700,000 people that is increasing at a rate of 2.8% annually (Birdsall & Fukuda-Parr 2002). On Moheli, the least densely populated of the Comoros Islands, the human population increased six-fold during the 20th century (Moulaert 1998), and it may have increased even faster on the more densely-populated Anjouan. Comorians also face a variety of social challenges: infant mortality is 61 deaths per 1000 live births, 25% of children less than 5 years of age are underweight, adult illiteracy is 44.1%, and life expectancy at birth is 60 years (Birdsall & Fukuda-Parr 2002). In addition, gross annual domestic income per capita is $380 (USD) (World Bank Group 2002).

Rural Comorians seeking economic development are often left with few opportunities, and many choose to clear montane native forest for subsistence agriculture or to exploit remaining forests at increased levels (Weightman 1987). Such exploitation results in greater erosion, increased flooding of lowlands, disappearance of permanent freshwater streams, increased susceptibility to cyclone damage, depletion of natural resources, and species extinctions (Reason *et al*. 1994, Moulaert 1998, Sewall 2002, Sewall *et al.* 2003).

Human pressures on Livingstone's flying fox habitat result from a high level of rural poverty and rapid population growth, combined with a low level of understanding of the needs of the species. Conservation efforts can help to reverse these trends by providing a net benefit for Livingstone's flying fox and for the Comorian people.

Legal framework

Livingstone's flying fox receives the highest level of legal protection available in the Union of the Comoros. It is listed as an 'integrally protected species' (list 1 of Boinali 2001), which prevents the capture or detention of flying fox individuals without a permit. It also expressly prohibits the killing of flying fox individuals; transport, purchase, sale, export or re-export of live or dead flying fox individuals or body parts; all disruption during the period of reproduction and raising of young; and the destruction of roosts.

Livingstone's flying fox's habitat also receives legal protection. Two tree species, *Khaya comorensis* and *Ocotea comorensis*, known to be used as roost trees by Livingstone's flying fox (Granek 2002), also are 'integrally protected species' (list one of Boinali 2001). In addition, although means of enforcement are not explicitly included in the legislation, the proposed Forest Law of the Union of the Comoros (Doumbe-Bille 2001) would limit forest clearing and forest fires on both public and private lands throughout the Comoros. The Forest Law would completely prohibit cultivation on all public forest lands with slopes greater than 35 %, and would prohibit cutting of trees on the same slopes in almost all cases. Fires would be prohibited in public forests and areas set aside for conservation or restoration, and on any private agricultural land where there is a risk that a fire could spread.

The proposed Forest Law would also provide the C*hargé des Forêts* the authority to establish protected areas and to designate areas to be reforested. Under the proposed law, this official also would have the authority to designate areas of special protection on public forest lands to protect fragile soils; the water table; natural springs, streams, or rivers; native forest tree species; or the habitats of the native flora or fauna. No such protected areas currently exist.

The international treaties which the Union of the Comoros has ratified reinforce this national legislation. Of special relevance are the Convention on Biological Diversity (United Nations 1992), and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (United Nations 1973).

The Convention on Biological Diversity aims to conserve biological diversity, sustainably use its components, and fairly and equitably share benefits from the use of genetic resources (United Nations 1992). The Union of the Comoros ratified the Convention in 1994, and in response has developed a National Biodiversity Conservation Strategy (Roby & Dossar 2000). This strategy highlights the importance of, threats to, and conservation recommendations for fruit bats of the Union of the Comoros (Sewall & Granek 2000).

The Union of the Comoros also ratified CITES in 1994. The main aim of CITES is to prevent extinction of vulnerable and endangered animal and plant species by protecting them from international trade. All species of flying fox (genus *Pteropus*) are accorded protection under Appendix 2 of CITES. Trade in Appendix 2 species, like Livingstone's flying fox, is permitted at an international level only under a permit provided by the country of origin (United Nations 1973). Such permits can only be offered when trade will not be detrimental to the survival of the species in the wild (United Nations 1973). Given the slow reproductive rate of flying foxes (Pierson & Rainey 1992), it is unlikely this condition could be met for any commercial export purpose for any flying fox species (Mickleburgh *et al.*1992, Mickleburgh 2002).

In addition, at a local level, there exist a variety of community- and religious-based rules that may benefit conservation. Although these rules apply on only a small scale, such rules are often better understood by local people and more strongly enforced by communities than are national laws.

Until now, lack of resources and personnel has limited implementation and enforcement of conservation laws in the Union of the Comoros. Nevertheless, this legal framework provides broad support to the actions proposed in this conservation plan.

Previous conservation plans

A global plan for the conservation of Old World fruit bats (Megachiroptera: Pteropodidae) was developed by Mickleburgh *et al.* (1992). In this plan, *Old World Fruit Bats: An Action Plan for their Conservation*, conservation of island bat species (such as Livingstone's flying fox) was listed as the second-most important overall global priority for fruit bat conservation. In addition, the plan provides specific recommendations for Livingstone's flying fox conservation, which include population monitoring, establishment of forest reserves, habitat protection outside of forest reserves, ecological research on feeding ecology and population biology, environmental education, and the establishment of captive breeding colonies. The last activity, the establishment of captive breeding colonies for Livingstone's flying fox, was highlighted as one of the 20 highest priority projects globally (Mickleburgh *et al.* 1992).

A species action plan was created to orient Livingstone's flying fox conservation efforts from 1995 to 2000 (IUCN 1994). Goals included the maintenance of an *ex situ* captive-breeding program, the continuation of a roost-monitoring program in the wild, the establishment of protected areas, ecological research, and further evaluation of conservation status. No protected areas were established during this period, but some progress (noted below in background sections for each program of the conservation strategy) was made toward the other goals.

Mission

In 1998, the government of the Union of the Comoros and its international conservation partners identified the need for a new conservation plan for Livingstone's flying fox (UNDP 1998). This plan would update and be much more comprehensive than the previous one. It would coordinate the disparate and sometimes overlapping conservation activities undertaken by local, national, and international organizations. It would also gather the diverse, widely scattered, and growing set of published and unpublished scientific information on Livingstone's flying fox into one easily understandable document that would be accessible from within the Comoros. The present document, the *Conservation Action Plan for Livingstone's Flying Fox* has been developed to meet these needs.

The overarching framework of this plan recognizes the urgent imperative of benefiting this critically endangered species, the ecological importance of this species for the rainforest ecosystem it inhabits, the exceptionally high rates of species endemism in this rainforest, the critical importance of the forest for rural livelihoods, and need to relieve rural poverty in the Comoros. The mission of this Conservation Action Plan is therefore *to conserve Livingstone's flying fox and its rainforest habitat, while also benefiting Comorian biodiversity and the Comorian people.*

Broad Aims

Nine broad aims support this mission, as follows:

A. Identify and protect roost and foraging resources that are crucial to the survival of Livingstone's flying fox,

B. Manage forest areas for the benefit of Livingstone's flying fox,
C. Foster local, national, and international appreciation for Livingstone's flying fox, and raise awareness of the threats it faces,
D. Track population trends and improve estimation of the population size and conservation status of Livingstone's flying fox,
E. Increase scientific understanding of the ecology and biology of Livingstone's flying fox,
F. Maintain a captive population with the potential for future reintroduction into the wild, while increasing opportunities for scientific research, environmental education, and fund-raising,
G. Address important but indirect threats to Livingstone's flying fox, and maximize benefit to all Comorian native biodiversity and the Comorian people by coordinating with other conservation activities and organizations
H. Increase the capacity of Comorians to study, sustainably manage, and conserve their environment, and
I. Improve implementation of this conservation strategy and future conservation efforts through a process of evaluation and feedback.

Conservation Strategy

Part two of this *Conservation Action Plan*, the Conservation Strategy for Livingstone's flying fox, is designed to meet the above mission and broad aims. The strategy is comprised of seven parallel programs. The first seven aims outlined above will each be met through implementation of a program designed to directly address it. The programs can each stand alone, but they are complementary and overlapping, and each program indirectly supports other aims.

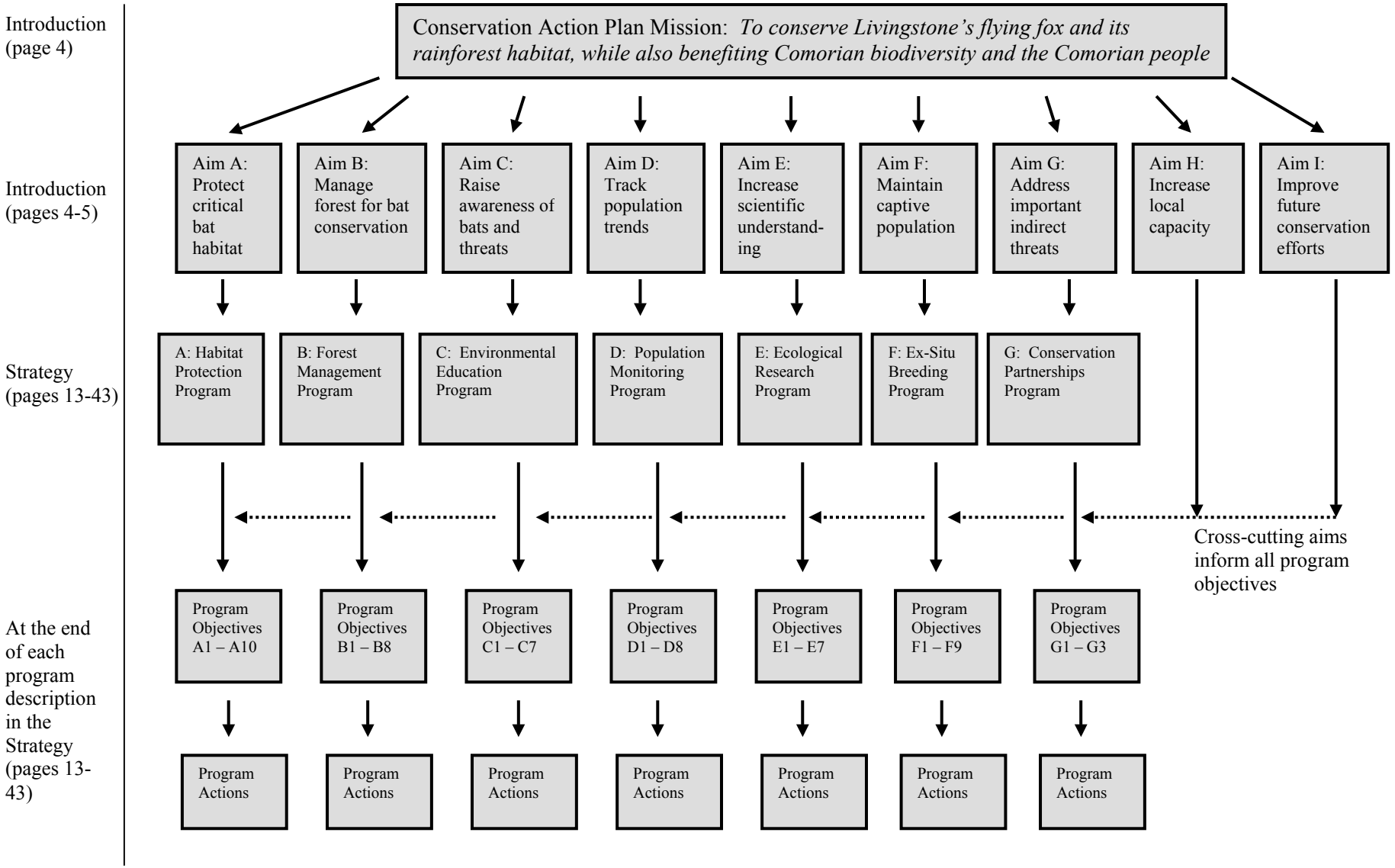
The last two aims relate to capacity development (capacity building) and evaluation. With a strong element of capacity development, local people will become more empowered to improve their situation, and the successes of the conservation program will become more firmly entrenched. With timely evaluation, lessons learned and new scientific information will be integrated into an improved approach to conservation. As capacity development and evaluation are intimately connected to every other broad aim of this *Conservation Action Plan*, these latter two aims have been integrated into every program, rather than standing alone as separate programs. A diagram of the organization of this Conservation Action Plan is presented in Figure 2.

Implementation

Implementation of the conservation strategy will be coordinated by the national government of the Union of the Comoros and the island governments of Anjouan and Moheli. In addition to coordinating the strategy, these agencies can provide leadership in implementing the conservation strategy, expertise in legislation, and facilitation of cooperation between local and international non-governmental organizations and funding agencies. However, both local involvement in, and international support for the plan's implementation will be essential to the success of the conservation strategy.

National non-governmental organizations and village associations throughout the Comoros Islands are exceptionally active, stable, and well supported by local people. Given sufficient support, these local organizations have tremendous potential to take a lead role in implementing the strategy. Regional collaborations with other conservation groups in the western Indian Ocean region (such as conservation efforts for the Critically Endangered Pemba flying fox (*Pteropus voeltzkowi*) and the Critically Endangered Rodrigues flying fox (*Pteropus rodricensis*)) would benefit Livingstone's flying fox conservation activities through an exchange of information and experiences. The continued involvement of the broader international community will greatly benefit the development and implementation of the Livingstone's flying fox conservation strategy through contributions to planning, technical assistance, scientific advice, and funding. The potential for success in implementing the conservation strategy is strong if local groups can take a strong role, under the leadership of national NGO's and with support from regional and international groups.

Figure 2. Organization of the *Conservation Action Plan for Livingstone's Flying Fox*.



Program objectives and actions

For each of the seven programs in the conservation strategy, several broad program objectives are presented and prioritized. In addition, key actions are highlighted to support each program objective. These actions are intended to be specific enough to clearly measure success, but general enough that implementing organizations can adapt them to changing circumstances. The actions chosen are those likely to have the highest likelihood of success, given the local economic, political, and cultural realities.

It should be noted that the information presented here represents the best current understanding of the conservation status and ecology of Livingstone's flying fox, and the objectives and actions presented here are based on this knowledge. Program objectives and actions may need to be modified based upon new information about Livingstone's flying fox and/or evaluation of past activities.

Potential partner organizations

For the actions proposed in this plan, potential partner organizations have been identified which can help the governments of the Union of the Comoros and of Moheli and Anjouan to implement the strategy. The list of potential partner organizations follows. This list is not comprehensive, and new partner organizations may emerge during planning for and implementation of the conservation strategy. More specific details about the roles of each organization in the implementation of this *Conservation Action Plan* will be developed as part of separate consultative planning efforts.

Potential Comorian partner organizations

- Action Comores antenne Anjouan
- Associations villageoises Ulangas, Anjouan and Moheli
- Centre de Ressources de Mohéli
- Centre National de Documentation et de Recherche Scientifique (CNDRS)
- Chargé de l'Eco-Tourisme de Mohéli
- Chargé des Forêts
- Communes and Mairies
- Direction des Eaux et Forêts
- Direction National de l'Environnement
- Direction du Plan
- Fonds d'Aide au Développement Communautaire (FADC)
- Maison des Epices
- Médias
- Ministère de l'Agriculture, de la Pêche, de l'Industrie, de l'Artisanat, et de l'Environnement de l'Union des Comores
- Ministère de la Coopération, de l'Equipement, et de l'Environnement d'Anjouan
- Ministère du Développement Rural et de l'Environnement de Mohéli
- Ministère de la Santé, Affaires Sociales, et de la Population d'Anjouan
- Ministère des Finances, Budget, Plan, et Tourisme d'Anjouan
- Ministères de la Justice
- Ministères de l'Education
- Ministères de l'Intérieur
- Ministères des Travaux Publics
- Parc Marin de Mohéli
- Projet Activités Habilitantes, Grande Comore
- Services des Douanes
- Société Comorienne d'Electricité et d'Eau
- Université d'Anjouan
- Université des Comores, Grande Comore

Potential international partner organizations

- Action Comores – International, United Kingdom
- Advisory Committee on Science and Conservation of Livingstone's flying fox (ACSC) (a new committee, to be developed as part of this *Conservation Action Plan*. See section E of the conservation strategy)
- Alliance Franco-Comorienne
- American Zoo and Aquarium Association (AZA)
- Bat Conservation International, USA
- Bat Conservation Trust, UK
- BirdLife International, UK
- Bristol Zoo Gardens, United Kingdom
- CARE-USA
- Captive Breeding Specialist Group of the World Conservation Union (IUCN-CBSG)
- Chiroptera Specialist Group of the World Conservation Union's Species Survival Commission (IUCN SSC-CSG)
- Conservation International, USA and Madagascar
- Durrell Wildlife Conservation Trust , British Isles (formerly Jersey Wildlife Preservation Trust) and Madagascar
- European Association of Zoos and Aquaria (EAZA)
- Fauna and Flora International, United Kingdom
- Global Environmental Facility
- Lubee Bat Conservancy, USA
- Mauritian Wildlife Foundation, Mauritius
- Projet Français de Développement Local
- Terre & Faune, Switzerland
- United Nations Development Program (UNDP), Grande Comore
- Wildlife Conservation Society, Madagascar
- World Conservation Union East Africa Regional office (IUCN-EARO), Nairobi, Kenya

Livingstone's flying fox colonies

Through extensive surveys and collaboration with local villagers, international scientists and the non-governmental organizations Action Comores Anjouan and Action Comores International have identified and confirmed twenty-three Livingstone's flying fox colonies. Roost sites for each colony are described here for the islands of Moheli (Figure 3a and Table 1a) and Anjouan (Figure 3b and Table 1c). Through a series of roost counts, these scientists and organizations have also collected data on the relative sizes of colonies on Moheli (Table 1b) and Anjouan (Table 1d). All data from these figures and tables are from Clark *et al.* (1997b), Granek (2002), Action Comores (1992, 1993, 1994, 1997, 1999, 2004, 2006), Action Comores antenne Anjouan and Action Comores – International (*unpublished data.*), Sewall (*unpublished data*), Hawes and Sewall (*unpublished data*), and Granek (*unpublished data*). Although the data presented here are only for roost sites and do not include specific foraging sites, these data provide a strong foundation for targeting each of the conservation programs described in this plan.

Figure 3a. Livingstone's flying fox roost sites on Moheli.

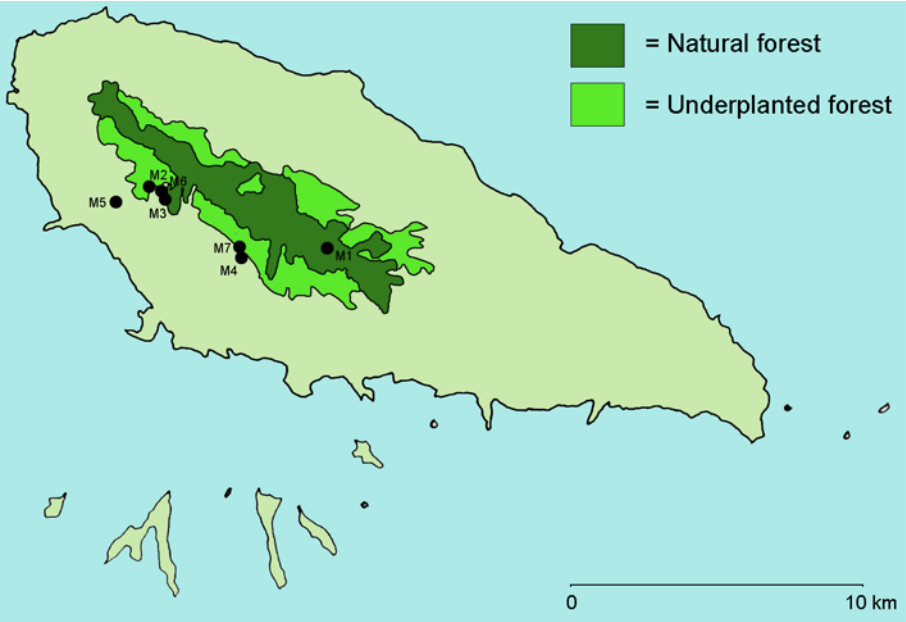


Table 1a: Moheli Livingstone's flying fox roost sites

Roost name	Nearest village	Name of roost monitor	Position*	Altitude (m)*	Single / mixed species	Notes / map ref.
Mlédjélé	Fomboni	Abdillah Moudhoir, a.k.a. « Moutombo »	S 12° 19.3' E 43° 43.3'	600	*P.l.* only	M1
Hassera-Ndrengé	Ouallah-Mirereni	Cheikh Moussa Iboura, a.k.a. "Bush"	S 12°18.1 E 43°40.2	400	*P.l* only.	M2
Kidogo-Basse	Ouallah-Mirereni	Mohamed Fahare	S 12°18.9 E 43°40.6	200	Mixed	M3
Hanakulemba	Ndrondroni	Rafiki Soilihi	S 12° 9.4 E 43° 41.9	450	Mixed	M4
Mkirini	Ouallah-Mirereni, Miringoni	Nikitoir Amir	S 12° 17.8 E 43° 40.0.	300	Mixed	M5
Hamoina-Chaburu	Ouallah-Mirereni	Karim Tomadoune	S 12° 18.5' E 43° 40.3'		*P.l* only.	M6
Hanye-Ngelé	Ndrondroni	Kolo	S 12° 19.2' E 43° 41.8'		*P.l.* only	M7

(M1): Previous name 'chez Pierre' in Action Comores (1992).This roost was appears to have been abandoned in 1995, but a colony was found again in the same zone in 2004.
(M2): Previous names Mirereni-Sera (Action Comores 1999), Sera-Niregé and Hassera-Nirengé. This colony abandoned the roost site when the roost tree fell in 2000, but was found nearby soon thereafter.
(M4): Previous name Hapemba.
(M5): Previous names Haka, Msakini. This colony appears to have been abandoned in 2005 or earlier, perhaps 2003.
(M7): Previous name: Hagné-Ngelé.

Table 1b. Moheli Livingstone's flying fox colony sizes

Roost name	Nearest village	Roost size**				
		Disused 0	Small <30	Medium 31-60	Large 61-90	Very large >90
Mlédjélé	Fomboni			●		
Hassera-Ndrengé	Ouallah-Mirereni				●	
Kidogo-Basse	Ouallah-Mirereni				●	
Hanakulemba	Ndrondroni		●			
Mkirini	Ouallah-Mirereni, Miringoni	●				
Hamoina-Chaburu	Ouallah-Mirereni		●			
Hanye-Ngelé	Ndrondroni			●		

Figure 3b. Livingstone's flying fox roost sites on Anjouan.

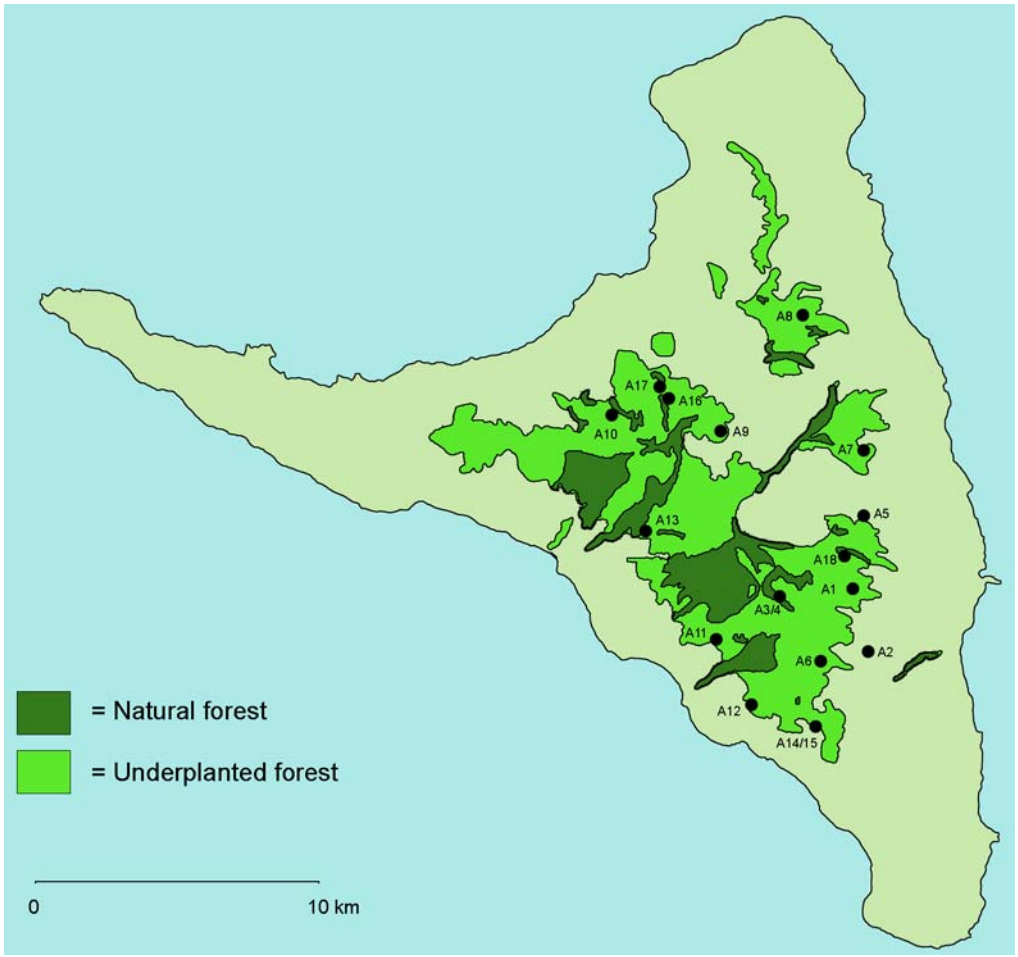


Table 1c. Anjouan Livingstone's flying fox roost sites

Roost name	Nearest village	Name of roost monitor	Position*	Altitude (m)*	Single / mixed species	Notes / map ref.
Mroni Papani	Salamani	Hissane Abdou	S 12° 15.9' E 44° 29.4'	785	*P.l.* only	A1
Dindri-Joumbé	Outsa	Ali Hamdou Moussa	S 12° 16.9' E 44° 29.6'	700	Mixed	A2
Moihajou	Ouzini	Saindou Moussa Toumani, aka 'S'	S 12° 16.0' E 44° 27.8'	1000	*P.l.* only	A3
Havoundre	Ouzini	Anli Moudine Attoumane	S 12° 15.8' E 44° 27.8'	940	Mixed	A4
Trondroni	Limbi	Bastoine Abdallah	S 12° 14.3' E 44° 29.5'	650	Mixed	A5
Forêt de Chava	Hadda	Abdillah Houmadi	S 12° 17.1' E 44° 28.6	960	*P.l.* only	A6
Bandra-Mromadji	Mromadji	Nahouda Souf	S 12° 12.9' E 44° 29.5'	500	Mixed	A7
Hamoigne-Panga	Bazmini	Nassurdine Ali Mari	S 12° 10.6' E 44° 28.3'	850	Mixed	A8
Drémélane	Dindri	Abdou Ahmed	S 12° 12.5' E 44° 26.6'	760	Mixed	A9
Massakini	Mpagé	Ali Djaha	S 12° 12.2' E 44° 24.3'	800	*P.l.* only	A10
Matulabé	Nindri-Pomoni	Hamidoune Oussene	S 12° 16.7' E 44° 26.5'	595	*P.l.* only	A11
Makini	Moya	Mohamed Abdou Nassim	S 12° 18.0' E 44° 27.20'	620	Mixed	A12
Yiméré	Lingoni	Mohamed Attoumane	S 12° 14.5' E 44° 25.0'	660	*P.l.* only	A13
Bwéjou	Kangani	Mohamed Combo	S 12° 18.6' E 44° 28.5	650	Mixed	A14
Kove	Kangani	Saindou Moussa	--	--	Mixed	A15
Mratsini	Sangani	Daoud Attoumane	S 12° 12.0' E 44° 25.4'	740	*P.l.* only	A16
Hombo	Hombo	--	S 12° 11.6' E 44° 25.4'	780	*P.l.* only	A17
Dziajou	Ouzini, Salamani	--	S 12° 15.2' E 44° 29.2'	670	*P.l.* only	A18

Notes:
(A1): Previous name Salamani in Action Comores (1997).
(A2): Previous names Outsa-Dindi with altitude 720 m, and Outsa-Hadda with altitude 660 m in Granek (2002).
(A3) & (A4): Possible previous name 'Ouzini-Nyambu' (? = Moihajou). Altitude of Havoundre given as 1000 m in Action Comores (1997).
(A5): Previous name Habebe.
(A6): Previous name Chava, near the village of (H)adda-Doueni.
(A7): Previous name Bandra-M'romagi; Mromadji (Granek 2000).
(A9): Previous names Dindi and Dremelani. Altitude given as 780 m in Action Comores (1992).
(A10): Previous names M'Page Valle / M'jah-M'Panje / Moija-Panja / Foret de Mpage / Masakini / Massakini Paje / Mkirini. Mpage altitude given as 840 m in Granek (2002).
(A13): Altitude 605 m Granek (2002).
(A14 / A15): Kangani was monitored at a single site ("Kangani") until December 1995.
(A17): This site appears not to have been used after 1995.
* Roost positions are given as determined by GPS and altimeter. Altitudes have an approximate accuracy of +/- 50 m in most cases. Due to inaccuracy of existing maps, some interpretation of roost positions has occurred through reference to field notes and triangulation from maps carried out during field visits, so that the positions plotted in the figures in this *Conservation Action Plan* may not always reflect these GPS fixes.

Table 1d Anjouan

Roost name	Nearest village	Roost size**				
		Disused 0	Small <30	Medium 31-60	Large 61-90	Very large >90
Mroni Papani	Salamani				●	
Dindri-Joumbé	Outsa		●			
Moihajou	Ouzini					●
Havoundre	Ouzini			●		
Trondroni	Limbi			●		
Forêt de Chava	Hadda			●		
Bandra-Mromadji	Mromadji			●		
Hamoigne-Panga	Bazmini					●
Drémélane	Dindri		●			
Massakini	Mpagé					●
Matulabé	Nindri-Pomoni					●
Makini	Moya			●		
Yiméré	Lingoni					●
Bwéjou	Kangani			●		
Kove	Kangani			●		
Mratsini	Sangani			●		
Hombo	Hombo	●				
Dziajou	Ouzini/Salamani				●	

** Roost size categories are calculated from means of biannual counts, using data from 1999-2002 where available.

Part II. Conservation Strategy for Livingstone's Flying Fox

A. Habitat Protection

The Comoros Islands are an area of exceptional endemism (Caldecott *et al.* 1996, Myers *et al*. 2000), yet Comorian diversity remains mostly unprotected. The only protected area in the Union of the Comoros is the Parc Marin de Mohéli, a marine park off the southern coast of Moheli. There are currently no terrestrial protected areas in the Union of the Comoros, despite the high proportion of Comorian biodiversity (Moulaert 1998, Louette 1999) that is found in the rainforests, including Livingstone's flying fox. Creation of such terrestrial protected areas was recommended in the global fruit bat action plan (Mickleburgh *et al.* 1992) and by several organizations (IUCN 1994, Action Comores 1994, Action Comores 1997, United Nations Development Programme 1998). Protection of Livingstone's flying fox's critical habitat is a top priority, and is urgently needed.

Roost habitat conservation

Livingstone's flying fox lives in colonies typically ranging in size from 15 to 150 individuals, at only 23 known roost sites (Table 1; Figure 3). The species appears to be heavily dependent on these existing roost sites, possibly due to constraints on altitude (200 m to 1100 m), aspect (generally southeast-facing slopes, though a few are found on northeast- and southwest-facing slopes), microclimate (shielded from mid-day sun), and characteristics of roost trees (emergent trees) (Granek 2002). Sites with such physical characteristics that remain forested are becoming rarer. Bats express seasonal variation in roost use, and roosts are typically mixed by sex, though there is one observation of sexual segregation at a roost; seasonal variation and sexual segregation are seen in other *Pteropus* species.

When a local farmer cut one of the roost trees at Dindri-Joumbé on Anjouan, the colony simply shifted to the remaining roost tree, and when that fell in a cyclone, the colony shifted to another nearby location (I. Saïd, pers. obs.). The Hassera-Ndrengé colony on Moheli also shifted to remaining roost trees and new ones nearby when one of the old roost trees fell (apparently due to natural causes) (B.J. Sewall, E.F. Granek, C.M. Iboura, pers. obs.). Another roost site, Mlédjélé on Moheli, disappeared when the roost tree and several of the surrounding trees were cut in 1995 (Action Comores 1997), but by 2005 bats had returned to the same area, which had undergone some natural regeneration. However, the Mkirini roost on Moheli and the Hombo roost on Anjouan have disappeared and not reappeared. Granek's (2002) research, the long history of occupancy at some roost sites (Action Comores 1999), and these instances suggest that these bats are faithful to roost areas, and suggest that the retention of sufficient emergent trees at known sites with appropriate physical characteristics is essential for Livingstone's flying fox conservation.

A few large roost sites, namely Moihajou (near Ouzini), Hamoigne-Panga (near Bazmini), Massakini (near Mpagé), Matulabé (near Nindri-Pomoni), and Yiméré (near Lingoni), appear to contain more than half of the known population of Livingstone's flying fox. These 5 roost sites should therefore be strongly considered for protection. To ensure maintenance of genetic diversity in the wild population, it also would be prudent to protect colonies from diverse geographical areas. In particular, one or more roost sites on the island of Moheli should be protected. The largest roost sites on Moheli are Hassera Ndrengé and Kidogo-Basse.

Habitat protection is largely dependent on the participation and involvement of local communities, thus the final selection of the specific roost sites to target for protection should depend upon an evaluation of the motivation and enthusiasm of the communities of nearby villages for participation in a conservation program. Recommendations for a reserve at the Yiméré roost site (Lingoni) were made by Action Comores-International to the Directeur General de l'Environnement in 1994 (Action Comores 1994), but no action has been taken thus far to establish the reserve. Evaluations of the social characteristics of the villages of Lingoni (near the Yiméré roost site), Ouzini (near Moihajou), Nindri-Pomoni (near Matulabé), and Ouallah-Mirereni (near Kidogo-Basse and Hassera-Ndrengé) indicated that each of these villages would be suitable for conservation (Granek 2000), based on a strong local interest in Livingstone's flying fox and local motivation for

participating in conservation activities. Evaluations were not undertaken at Bazmini and Mpagé, villages near the other large roost sites, but such evaluations would be beneficial.

Some roost sites are in areas almost completely modified for agricultural use, such as Dindri-Joumbé, or in mixed agricultural-forest habitat, such as Drémélane, Makini, and Bandra-Mromadji (Granek 2002). However, the colonies at these roost sites tend to be small, and may not persist over the long term since natural regeneration (which can provide new emergent trees for roosts to replace old trees that fall) is inhibited by human activity.

For these reasons, not only roost trees, but also additional nearby trees should be protected to ensure long-term availability of key roost sites. In addition, edge effects may be important at long distances from the edge of a forest fragment. For example, tree mortality may be increased at up to 300 m from a forest edge, and wind disturbance may be increased at up to 400 m from a forest edge (Lewis 1998, Laurance *et al* 1998, 2000, 2002). Both issues are of concern to roost site conservation efforts, since the number of suitable emergent trees in an area may be limited, and so, where possible, protected areas extending greater than 400 m beyond the roost tree cluster should be attempted.

Nonetheless, the size of such protected areas may be limited by the availability of intact or restorable land, and by other human considerations. One very important factor at Livingstone's flying fox roost sites is the effect of microclimate (Granek 2002). Microclimatic factors like relative humidity and air temperature may be affected beyond 100 m from a forest edge (Lovejoy *et al.* 1986, Kapos 1989, Laurance *et al.* 2002). Therefore, if the preferred buffer of 400 m is not attainable, all roost site protected areas should at least include a buffer of forest greater than 150 m in each direction beyond the periphery of the roost tree cluster (thus a total area of greater than 7 hectares) in order to reduce the negative effects of changed microclimates at Livingstone's flying fox roost sites.

Foraging habitat conservation

Livingstone's flying fox diet varies strongly by season (Sewall 2002), and may also vary within a season. Livingstone's flying fox appears to specialize on a few key resources, while opportunistically using additional tree species (Sewall 2002). *Ficus lutea* in particular appears to be a critical fruit resource for Livingstone's flying fox; other important fruit resources are *Ficus antandronarum, Anthocleista grandiflora,* and *Ceiba pentandra* (Sewall 2002). *Ceiba pentandra* also provides an important seasonal flower resource from April to July (Trewhella *et al.* 2001). Several additional tree species are also used (Action Comores 1997, Trewhella *et al*. 2001, Sewall 2002). Less frequently used food resources may provide essential micronutrients or serve as critical food resources during times of scarcity of more preferred or abundant resources (Sewall 2002). Further foraging ecology observations throughout the annual cycle may reveal additional important food resources.

Sewall (2002) recommended a hybrid strategy for conservation of Livingstone's flying fox foraging habitat, focusing on both conservation of the key food resources, and also protection of native forest areas to ensure that other infrequently used and seasonal food resources remain available. Key tree species could be conserved through environmental education targeted at farmers, by recommending or providing incentives to farmers to encourage the retention of important 'bat trees' (especially rare but important native tree species like *F. lutea*) in agricultural areas (Sewall 2002). Alternatively, legislation or targeted management practices may help to maintain or increase numbers of critical food tree species. Such actions will help to maintain bat food resources in agricultural and mixed agricultural-forest lands.

Protection of foraging habitat may be accomplished by setting aside either large forest areas or several smaller patches of forest. Protected areas should cumulatively be large enough to maintain the viability of tree species, and contain enough individual trees to provide sufficient fruit and flowers continually throughout the year to maintain a viable population of Livingstone's flying fox. The particular areas selected as a reserve should ideally be known important foraging areas for Livingstone's flying fox. (It is possible for local personnel to determine this, for example through the vantage point observation technique described in Sewall 2002). However, if such lands cannot be protected, and if sufficient food resources will remain in unprotected areas over the medium term, then currently cleared or degraded land might be included as protected areas, and later returned to native forest through regeneration or restoration management. Since Livingstone's flying fox ranges

widely while foraging (Action Comores 1992, I Saïd, A. Feistner pers. obs., B. Sewall, pers. obs.), and since large areas are generally required to support frugivores in tropical forests (Terborgh & Winter 1980), foraging protected areas should be as large as can be feasibly protected. If no large forest areas can feasibly be protected, then at least one foraging area should be protected per target roost site. Due to the high mobility of the bats, foraging sites need not be adjacent to roost sites.

Road construction

Potential effects of road construction on wildlife are numerous, and have had well-documented negative effects in many areas of the world (e.g., Santos & Tabarelli 2002). Road construction on Anjouan or Moheli through or near to forested areas has the potential to cause severe indirect effects on Livingstone's flying fox through loss or degradation of roosting or foraging habitat. These include: (1) loss of roost trees if a road passes through a roost tree cluster, (2) effects of road noise, pollution, and disturbance on Livingstone's flying fox roost sites when roads pass near a roost tree cluster, (3) increased wind and storm damage and other edge effects at roost sites following fragmentation of a primary or secondary forest by a road, (4) loss of Livingstone's flying fox foraging habitat when roads pass through remaining native primary or secondary forest habitat or agricultural areas with large trees important to the bats, (5) a long-term effect on roosting or foraging sites from the introduction of invasive plants spread from road corridors, or (6) subsequent clearing of roosting or foraging habitat for agriculture, logging, firewood, or other purposes after the road construction affords increased access.

To maintain the integrity of Livingstone's flying fox roost and foraging sites, environmental impact studies should be required prior to new road construction. Construction of roads through any remaining areas of native primary or secondary forest on Anjouan or Moheli is unlikely to be compatible with Livingstone's flying fox conservation.

Land tenure and human population pressures

Specific attention should be paid to the development of an effective and economically feasible strategy to acquire or otherwise set aside land containing critical habitat of Livingstone's flying fox. This strategy should identify means to protect critical Livingstone's flying fox habitat, while maintaining or increasing support by local communities for these measures, and ensuring recognition and support of the protected areas by island and national government.

However, land tenure in the Comoros Islands, and on Anjouan in particular, is complex (A. Sidi, pers. comm.). Any attempt to set aside land for conservation purposes is likely to confront competing claims to the land. In many areas, local government, national government, and local farmers all have claims to the same land. In order to assure cooperation by all parties, a fact-finding and negotiation process may be necessary prior to establishment of protected land areas.

The strategy should take into consideration regional variations in land tenure traditions, the disputed nature of local and governmental claims to land, population and economic growth trends, capacities of actors involved in the conservation process, and the long-term sustainability of the conservation mechanisms. The outreach strategy utilized in the creation of the Parc Marin de Mohéli may be used as a model for the creation of such forest protected areas.

Broad Aim A: Identify and protect roost and foraging resources that are crucial to the survival of Livingstone's flying fox.

Habitat Protection Program objectives and actions

A.1. Engage in collaborative conservation planning to lay the groundwork for forest reserve establishment in the Comoros.

- A.1.a. Completion of an ecological study of potential reserve sites to measure, at each site, the abundance of bats, species diversity, human impacts, and restoration needs.
- A.1.b. Completion of a social study to better understand the interests and motivation for conservation of villagers living near potential reserve sites, determine potential rules to govern the reserves, and clarify conflicting land claims.

A.1.c. Proposal of a detailed plan for sustainable protection of critical bat habitat and a balanced system for co-management of reserve sites.

A.2. Establish, as a first step, protected areas at the 5 largest roost sites on Anjouan and the 2 largest roost sites on Moheli. Protected areas should extend at least 150 m in each direction beyond the known roost tree cluster.

A.2.a. Employment of a Comorian habitat protection coordinator to coordinate the overall Habitat Protection Program and support local management committees.

A.2.b. Training of habitat protection coordinator.

A.2.c. At each proposed forest reserve, formal approval and implementation of protected area statutes by all stakeholders, the local community, and the government.

A.2.d. For each forest reserve, formal approval and implementation of a co-management program by all stakeholders, the local community, and the government.

A.2.e. At each village near a forest reserve, the creation of a village forest management committee.

A.2.f. Clear boundary demarcation of each forest reserve.

A.3. Identify critical foraging habitat associated with targeted roost sites.

A.3.a. Study, near each targeted roost site, of critical foraging sites for Livingstone's flying fox.

A.3.b. Prioritization of foraging sites possible to protect near targeted roost sites, taking into consideration year-round availability of fruit and flower resources, and maintenance of the regenerative capacity of native forests.

A.4. Protect rare native tree species, such as *Ficus lutea* (Mvuvu), that provide critical food resources to Livingstone's flying fox.

A.4.a. Development of an environmental outreach program for landowners or local communities to encourage farmers to protect in their fields important bat food species.

A.4.b. Completion of a feasibility study of a system that would provide economic benefits to farmers who protect in their fields large trees of species important to bats.

A.4.c. Addition of rare tree species that are critical for Livingstone's flying fox foraging, like *Ficus lutea* (Mvuvu), to the national list of protected species.

A.5. Protect critical foraging habitat that can feasibly be protected given local human considerations.

A.5.a. Development of a strategy to protect bat foraging areas, taking into consideration the priority sites identified as well as legal land claims and traditional land tenure issues.

A.5.b. According to this strategy, protection of foraging sites near each targeted roost site. One large and / or several small foraging areas should be protected for each targeted roost site.

A.5.c. At each proposed forest reserve, formal approval and implementation of protected area statutes by all stakeholders, the local community, and the government.

A.5.d. For each forest reserve, formal approval and implementation of a co-management program by all stakeholders, the local community, and the government.

A.5.e. Clear boundary demarcation of each forest reserve.

A.6. Increase support in local communities for setting aside land for conservation purposes.

A.6.a. Increase in sustainable development efforts near forest reserves, especially in sustainable agriculture and forestry, health, and education.

A.6.b. Increase in efforts to establish small-scale ecotourism near forest reserves.

A.6.c. Capacity-building of village forest management committees.

A.7. Facilitate involvement of local communities in land use decisions related to conservation.

A.7.a. Consultation with local communities on the selection and the size of areas to protect.

A.7.b. Consultation with local communities on all aspects of management and rules of forest reserves.

A.7.c. Identification, with local participation, of target foraging areas to protect for each targeted roost site.

A.7.d. Creation and training of a village forest management committee in each village near a forest reserve.

A.8. Conduct an environmental impact assessment, incorporating direct and indirect effects as well as short- and long-term effects of road construction on Livingstone's flying fox and its habitat, prior to approving any new road construction projects that would pass near primary or secondary forest or mixed forest-agricultural areas.

A.8.a. Evaluation of all potential road construction projects passing near primary or secondary forests, or through mixed forest-agricultural areas.

A.9. Carefully screen all potential new road construction projects that would pass through primary or native secondary forest, or would otherwise affect the integrity of Livingstone's flying fox roost or foraging sites.

A.9.a. Establishment of protocols for screening potential road construction projects to avoid those that would negatively affect existing native primary and secondary forest or the integrity of Livingstone's flying fox roost or foraging sites.

A.10. Improve this Habitat Protection Program and plan future actions.

A.10.a. Evaluation of the contribution of this Habitat Protection Program to the conservation of Livingstone's flying fox and its rainforest habitat, and to Comorian biodiversity and the Comorian people.

A.10.b. Development of a long-term plan to protect additional roost and foraging sites.

B. Forest Management

It will be essential to manage both protected area lands (once established) and lands without formal protection to ensure that sufficient habitat remains suitable for Livingstone's flying fox, while also benefiting other Comorian biodiversity. Management and reforestation activities for the benefit of Livingstone's flying fox were recommended in *Old World Fruit Bats : An Action Plan for their Conservation* (Mickleburgh *et al.* 1992). The need for effective management and reforestation activities to benefit Livingstone's flying fox has only grown more important since then.

Roost site management

Reforestation of cleared areas near roosts may improve the desirability of roost sites to Livingstone's flying fox. Presence of forest canopy cover, especially with native tree species, is positively associated with Livingstone's flying fox roost sites (Granek 2002). In addition, conservation activities that maintain the forest canopy may result in microclimatic conditions (shading from mid-day sun in particular) that Granek (2002) also found were associated with Livingstone's flying fox roost sites.

If areas protected at roost sites had previously been modified, remaining native trees within this area should be protected, regeneration should be promoted where there has been disturbance, and activities that reduce regeneration of canopy trees, like underplanting, should be limited or eliminated.

Reforestation and other management activities should favor the growth of canopy tree species, especially those that may potentially become emergent, in particular those that are known roost tree species (Table 2). Natural regeneration is likely to promote growth of most of these tree species; underplanting reduces, sometimes severely, the future replacement of old canopy trees with new ones. In addition, new techniques may need to be developed to propagate some native tree species to direct and accelerate restoration efforts. Finally, as roost sites are places of rest for Livingstone's flying fox, human activity and noise near roost sites should be minimized, for example by reducing the number of trails that pass beneath roost trees.

Foraging area management

The key tree species used by Livingstone's flying fox as foraging resources are the following: fruit from *Ficus lutea*, *Ficus antandronarum*, and *Anthocleista grandiflora* (Sewall 2002), and flowers from *Ceiba pentandra* (a non-native species) (Trewhella *et al.* 2001, Sewall 2002). Also used, to a lesser extent, are fruit from *Ceiba pentandra*, *Callophyllum inophyllum*, and *Gambeya sp.*, and flowers from *Gyrostipula sp.* and an unknown species from the family Malphigiaceae (Sewall 2002) (Table 2). This list may not be exhaustive; more in-depth and longer-term foraging studies may reveal a broader diet range. Management objectives should include increasing the abundance of large individuals of critical bat food tree species, propagating these and other native tree species, and minimizing human activities that hamper regeneration of canopy trees, such as underplanting.

Human use

It is essential to develop management plans that are acceptable to and agreed upon by local communities. In some cases the most economical land use is protection of native forest – for example, on steep slopes where erosion would occur if forests were cut, or near stream banks where gallery forests can slow flash floods and maintain the permanence of rivers. Forests provide other ecological services valuable to local people, including increased soil fertility, pollination services, and protection from storm and cyclone damage. Community awareness of ecological services provided by the forest can contribute to developing a community consensus for protection and sustainable management.

Even land that would otherwise be highly prized for agriculture or other extractive uses could be protected if an economic benefit can be generated from non-extractive uses. One example of economic generation from land protection is ecotourism (see further details in program G, "Conservation Partnerships"). However, from a management perspective, it is important to consider in advance the potential for disturbance of Livingstone's flying fox roost and foraging sites. Rules

should be implemented to retain quiet, limit close approaches by tourists, and prevent harassment of the bats (e.g., by hitting roost trees or making loud noises or otherwise forcing bats to fly in order to see them better). Requiring a properly trained and locally authorized guide to lead all tourist visits can minimize many of these problems, and use of observation blinds may further limit disturbance to bats.

In more marginal lands, some conservation can be accomplished through a multiple-use approach to conservation. Common lands might be set aside, with the understanding that they would continue to be used as a community resource. Local people may still view conservation as a desirable alternative to clearing if some human use, such as collection of medicines or use of native fruit, for example, is allowed.

Broad Aim B: Manage forest areas for the benefit of Livingstone's flying fox.

Forest Management Program objectives and actions

B.1. Study the feasibility of restoration activities.
- B.1.a. Study of the feasibility of actions, actors, methods, and financial and training needs necessary for the implementation and sustainability of the Forest Management Program.
- B.1.b. Create a database of geo-referenced data and thematic maps to assist the management of forest reserves.

B.2. Develop local expertise in restoration of native forest.
- B.2.a. Employment of Comorian forester to coordinate the overall management of protected areas and support local management committees.
- B.2.b. Training of forester in forestry management techniques that will benefit Livingstone's flying fox and Comorian biodiversity.
- B.2.c. Training of forester in methods of community outreach and training of village forest management committees.

B.3. Restore lands contained within protected areas to native forest.
- B.3.a. Restoration of protected areas through reforestation and replacement of non-native trees with native ones.
- B.3.b. Encouragement of local participation in the establishment, restoration, and management of forest reserves.

B.4. Maintain year-round availability of fruit and flower resources for Livingstone’s flying fox.
- B.4.a. Retention of several foraging sites per bat colony.
- B.4.b. Encouragement of farmers to conserve in their fields tree species that are important bat foraging resources.
- B.4.c. Maintenance of a diversity of native tree species in the forest canopy.
- B.4.d. Enforcement of a prohibition on the use of chainsaws in native forest areas.
- B.4.e. Protection of trees and foraging sites at several altitudes.
- B.4.f. Develop recommendations to potential partner organizations for important bat food tree species to use in reforestation projects.

B.5. Maintain the capacity of protected forest areas to regenerate.
- B.5.a. Reduction in clearing of the understory of forest reserves.
- B.5.b. Maintenance of a diversity of native tree species in the forest canopy.

B.6. Re-establish vegetative characteristics preferred by Livingstone’s flying fox at roost and foraging sites.
- B.6.a. Retention of emergent trees at bat roost sites.
- B.6.b. Regeneration of tree species used by bats as roost trees.
- B.6.c. Retention of large fruiting canopy trees at bat foraging sites.
- B.6.d. Regeneration of tree species used by bats for food resources.

B.7. Develop local capacity to manage protected areas.
- B.7.a. Creation and initial training of a village forest management committee in each village near a forest reserve.

B.7.b. Ongoing training of village forest management committee by the coordinator of Forest Management Program.

B.7.c. Regular training of village forest management committees and exchanges between committees.

B.8. Improve this Forest Management Program and plan future actions.

B.8.a. Evaluation of the contribution of this Forest Management Program to the conservation of Livingstone's flying fox and its rainforest habitat, and to Comorian biodiversity and the Comorian people.

B.8.b. Measurement of current levels and types of human use of forest reserves.

B.8.c. Measurement of current levels and types of Livingstone's flying fox use of forest reserves.

B.8.d. Development of long-term forest management plans that allow sustainable management of forest reserves, sustainable use of forest resources, and conservation of Livingstone's flying fox habitat.

Table 2: Tree species used for roosting and foraging. (Trewhella *et al.* 2001, Granek 2002, Sewall 2002, Sewall unpublished)

Scientific name	Family	English	French	Shindzouani	Shimwali	Roosting tree	Foraging tree
Nuxia pseudodentata	Loganiaceae			Mwaha		•	
Gambeya sp.	Sapotaceae			Mimba njeu, Mfantsi, Mfuantsi, Mbandjeu		•	•
Brachylaena ramiflora	Asteraceae			Mshelele, Mgu		•	
Khaya comorensis	Meliaceae			Mpori, Mlandrema, Mtakamaka	Mtakamaka	•	
Ocotea comorensis	Lauraceae			Mrobwe	Mkafure	•	
Terminalia catappa	Combretaceae	Tropical almond	Badamier	Munyamba, Myamba	Mkadare	•	
Albizia galaberima	Mimosaceae			Mkazimanga, Mdjendje, Mzilandze	Mdjendje	•	
Ficus bojeri	Moraceae	Fig	Figuier	Mshui madji	Mouhouyoumadj	•	•
Ficus lutea	Moraceae	Giant-leaved fig	Figuier	Mvuvu	Mvuvu	•	•
Ficus antandronarum	Moraceae	Fig	Figuier	Mzingara, Mshimbuhu, Mshoumbwi	Mzingara	•	•
Anthocleista grandiflora	Loganaceae			Mpapa, Mdongori	Mpapa, Mdongori		•
Ceiba pentandra	Malvaceae	Kapok	Fromager, Kapokier	Mpampafuma	Mpambafuma		•
Callophyllum inophyllum	Clusiaceae			Mkorwa, Motrondro	Motrondro		•
Gyrostipula comorensis	Rubiaceae			Mwiri mudu			•
Unknown	Malphigiaceae			Karagnombe			•
Unknown	Icacinaceae			Chivoundze		•	

C. Environmental Education[3]

Environmental education programs can increase ecological awareness, foster more favorable attitudes towards the environment and promote natural resource conservation (Jacobson 1991). They can produce significant attitude changes in their target audience (Jacobson 1987; Padua 1994), and may be crucial to successful conservation work (Jacobson & McDuff 1998).

Old World Fruit Bats: An Action Plan for their Conservation (Mickleburgh *et al.* 1992) recommended the establishment of environmental education programs to address the role of Livingstone's flying fox in the ecology of the forest, and the effects of deforestation and roost site disturbance on the bats. As a result of this, in 1992, *Action Comores – International* initiated an environmental education program that has since been continued by *Action Comores antenne Anjouan* and *Projet Biodiversité* in association with volunteers from *Action Comores – International*, visiting scientists, U.S. Peace Corps volunteers, *Ulanga* groups (village-based non governmental conservation organizations), and *Projet Biodiversité* field staff. These groups have presented environmental education to villages neighboring bat roosts, government officials, and the broader public, informally and through town meetings, local radio and television broadcasts, and local environmental events (such as World Environment Day). The program used Livingstone's flying fox as a flagship species for forest biodiversity protection, stressing the interdependence of bats, forests, and people. The environmental messages were pitched at all age groups. Educational materials used images and examples entirely taken from, or related to, the Comoros archipelago.

In a recent review of fruit bat environmental education program in the Comoros and other western Indian Ocean islands (Trewhella *et al.* 2005), the following aspects were deemed key elements of success: extensive prior planning, presentation in the local language, use of locally appropriate technologies, distribution through pre-existing networks of educators, local production of educational materials, strong local coordination, and capacity-development of local staff. These elements should be prominent in any future environmental education program to maximize the potential for clear communication of the message. This message should be clear, concise, targeted at an appropriate level, and based on accurate scientific information.

Past environmental education activities have raised awareness about the existence of Livingstone's flying fox, and the interdependence of bats, forests, and people (M. Moutui & B. Sewall, pers. obs). Some additional benefits of the environmental education program include an increased sense of pride in the existence of this endemic species, the contribution of information (e.g., the presence of roost sites) to the population monitoring and ecological research programs, and the creation of a network of local conservation groups and individuals that can be mobilized for future conservation activities (Trewhella *et al.* 2005). Given the successes of past environmental education efforts, and the continuing need for environmental awareness, environmental education efforts should be continued and enhanced to increase awareness of Livingstone's flying fox, the threats it faces, and actions that can be taken to improve its chances of survival.

Dissemination within the Comoros

Schools are a key means of information transfer because they can provide in-depth instruction to students. Providing a few lesson plans along with appropriate training to dynamic teachers can result in the transfer of in-depth information to a large number of students. *Collège* (middle school) may be the best group to target, as *collège*-aged students are old enough to understand complex ecological concepts and still attend school in large numbers (there is a high drop-out rate before and during *lycée*, or late secondary school).

Schools in the Union of the Comoros, however, have been prone to strikes and other interruptions, and in the recent past, some entire school years have been annulled in public schools. In addition to this vulnerability to instability, school-based education does not directly reach the entire community, including those in a position to make short-term choices about habitat destruction and protection. For these reasons, additional dissemination networks outside the school system should be targeted to spread accurate information about Livingstone's flying fox directly to local communities.

[3] Background information adapted from Trewhella *et al.* 2005.

In particular non-governmental organizations such as the local Ulanga groups and the roost monitoring network should be targeted, as these are more likely to include people living close to bat roosts. Other possibilities include video rental stores, taxi drivers' groups, mosques, marketplaces, radio, television, and other media.

Production of inexpensive materials such as stickers and leaflets in both French and Comorian (Shindzouani and/or Shimwali) have been shown to facilitate the spread of information by helping to initiate conversations about Livingstone's flying fox conservation (Trewhella *et al*. 2005). These materials may also be displayed on buildings and in taxis to raise awareness of conservation efforts. Use of the media, radio in particular, can also provide a means for disseminating information on Livingstone's flying fox conservation to a large audience. Images of Livingstone's flying fox would be strong candidates for presentation on Comorian stamps, money, postcards, headscarves, or shiromani cloth. Other promising possibilities include translation into Comorian and distribution of the Discovery Channel / Canal Plus *Land of the Giant Bats* video or production of other videos for educational purposes, and promotion of cultural events (dances, artwork competitions, theater, etc.) that focus on Livingstone's flying fox.

Key to the successful transmission of an environmental message in the Union of the Comoros will be the appointment and training of local environmental education coordinators to develop new materials and lesson plans, and to train community groups and school teachers to teach students and other audiences about Livingstone's flying fox and its habitat. Such local coordinators have been crucial in two other bat-related environmental education programs on the western Indian Ocean islands of Pemba and Rodrigues. A local perspective provides knowledge about local issues, attitudes, barriers, and opportunities; cost-effective production of locally appropriate educational materials; local personal investment in bringing about positive change; the potential for long-term local continuity in the environmental education program; and a reliable point of contact for local people and outside groups interested in environmental education.

International dissemination

Conservation efforts may also benefit when awareness is raised amongst a broader international audience. Bats in the Livingstone's flying fox captive breeding program are on display in the Jersey and Bristol Zoos; they serve as ambassadors for their species and other bat species, acting as a focal point for environmental education of zoo visitors. Almost one million people are estimated to have visited these establishments in 2000. In Bristol, the species and its plight is discussed in secondary schools. The natural history film *Land of the Giant Bats* has been produced and shown in Europe and the United States, funded by Discovery Channel and Canal Plus, and with the collaboration of several of the non-governmental organizations that have been involved in Livingstone's flying fox conservation. In addition, two popular articles about Livingstone's flying fox ecology and conservation have appeared in *BATS* magazine (Clark 1997, Sewall 2003b) and one in *Zoo Matters* magazine (Sewall 2003a), each reaching an audience of more than 12,000 readers. Several scientific presentations have reached a specialized international audience at scientific conferences. Conservation efforts for Livingstone's flying fox, including the education program, have been chosen as one of the success stories in the United Nation's document "Sustainable Development Success Stories: Special Issue on Small Island Developing States" (United Nations, 2001). These types of efforts have been successful, and should be continued.

Broad Aim C: Foster local, national, and international appreciation for Livingstone's flying fox, and raise awareness of the threats it faces.

Environmental Education Program objectives and actions

C.1. Develop environmental education programs and disseminate didactic materials to Moheli and Anjouan.

C.1.a. Employment of two local environmental education coordinators, one for Moheli and one for Anjouan.

C.1.b. Capacity-building of the two coordinators on community and school-based environmental education techniques, and on the biology of Livingstone's flying fox.

C.1.c. Provision of each coordinator with sufficient training and resources to develop the school- and community-based environmental education programs.

C.1.d. Development of teacher's manuals and other didactic materials to enable the application of the environmental education component of school curricula.

C.1.e. Development of teacher's manuals and other didactic materials appropriate for community-based environmental education.

C.2. Teach about the connection between human needs and the ecological services rendered by Livingstone's flying fox and its rainforest habitat.

C.2.a. Dissemination of lesson plans and educational materials to teachers and local community educators.

C.2.b. Training of Comorian teachers, principals, representatives of the Ministries of Education, and local community educators in the use of environmental lesson plans and educational materials.

C.2.c. Regular presentations in schools and communities.

C.3. Raise awareness of steps Comorians can take to contribute to the conservation of Livingstone's flying fox and its habitat.

C.3.a. Production and dissemination of information on Livingstone's flying fox and its habitat for the population of the islands of Moheli and Anjouan (e.g., radio and television broadcasts, videos, news articles, stickers, and brochures).

C.3.b. Meetings with landowners and other stakeholders.

C.3.c. Organization of school environmental clubs.

C.3.d. Organization of community meetings (e.g., Ulanga associations, women's associations, farmers' associations, distillers' associations, and loggers).

C.3.e. Establishment and annual celebration of a National Livingstone's Flying Fox Day.

C.4. Put in place on Anjouan a documentation center for Livingstone's flying fox and its habitat, and support the existing documentation center for Livingstone's flying fox on Moheli (Maison de Livingstone at Ouallah-Miréreni).

C.4.a. Identification of an appropriate site for the documentation center on Anjouan.

C.4.b. Definition of the role and activities of the documentation centers.

C.4.c. Research and collection of documents for the two centers.

C.4.d. Provision of human and financial resources to the documentation centers.

C.4.e. Capacity-building of the documentation centers' staffs.

C.5. Present information to the international public about the ecology and conservation of Livingstone's flying fox.

C.5.a. Continuation of education programs on Livingstone's flying fox and its conservation to visitors of zoos involved in the ex-situ breeding program.

C.5.b. Publication of articles and presentations at scientific conferences on Livingstone's flying fox and its conservation.

C.5.c. Dissemination of information through an Internet site.

C.6. Promote exchanges among environmental educators in the Comoros, in the western Indian Ocean region, and internationally.

C.6.a. Identification of environmental educators in the Comoros, in the western Indian Ocean region, and internationally.

C.6.b. Contribution to the organization of environmental education conferences.

C.6.c. Creation of a conservation network in the Comoros and the region.

C.6.d. Establishment of links between the Environmental Education Program in the Comoros and environmental educators in zoos involved in the ex-situ breeding program.

C.7. Improve this Environmental Education Program and plan future actions.

C.7.a. Evaluation of the contribution of this Environmental Education Program to the conservation of Livingstone's flying fox and its rainforest habitat, and to Comorian biodiversity and the Comorian people.

C.7.b. Development of a long-term plan to continue environmental education on Livingstone's flying fox, and expand to other elements of Comorian biodiversity.

D. Population Monitoring

Population monitoring programs are essential to detect and describe long-term trends in the status of a species, or to provide an early warning of precipitous short-term population declines, and to monitor the effects of conservation intervention strategies (Nichols & Conroy 1996). Monitoring programs are difficult to establish, in part because they require effort over an extended time period before population trends can be detected. This is because the degree of natural variability in the population must be determined before data can be analyzed for population trends. Understanding this variability is a major undertaking in monitoring programs, and requires multiple years of data.

The Livingstone's flying fox population monitoring program was initiated in 1992 by Action Comores – International. It trained local observers, known as roost monitors, to conduct the necessary observations, and it created the infrastructure necessary to collect and organize the data. The local aspect of the population monitoring program started (as a pilot program involving one roost) in 1992. Pilot monitoring of additional roost sites was undertaken from 1992-1995, with data collection for the monitoring program beginning formally in mid-1995 (Action Comores 1999). Monitoring data has been collected continually since then (Action Comores 2006).

Since 1995, the field activities of the population monitoring program have been run by Action Comores antenne Anjouan and the Ulanga village associations, with continuing technical support from Action Comores – International. The monitoring protocol involves simultaneous monthly visits to all the twenty-three known roost sites by local roost monitors, and larger simultaneous biannual visits to all the roost sites by teams of Ulanga volunteers. Data are collected and organized by Action Comores antenne Anjouan, and sent to Action Comores – International for analysis.

The Population Monitoring Program has encountered some challenges. With roost monitors scattered in remote villages across two islands, maintaining the quality and consistency of the data has been difficult. In particular, roost monitoring techniques have sometimes been unevenly applied, even by roost monitors with the same training (E. Granek, pers. obs.). Funding for roost monitors' salaries was pieced together in a patchwork manner through funds raised primarily through grants from a number of organizations by Action Comores International until 2001, and gaps in funding have occurred since 2004. Formal statistical analysis of the monitoring data collected from 1999 to present has not yet been fully completed.

Some steps have been taken to address these issues. The data collection portion of the program has undergone many improvements. Major gaps in data, once common, are now rare. Data were collected at all roost sites even through the international embargo of Anjouan, when communication was cut off with the outside, and little fuel was available to travel from one region of the island to another. Roost monitors at all field sites are trained in locating bat roosts, bat species identification, bat counting techniques, and in field data entry onto standard data sheets. According to a pre-determined schedule, the collected data are sent to a central collection point.

An evaluation of the roost monitoring program by Action Comores – International (Action Comores 1999) suggested several institutional improvements, which have subsequently been undertaken. One result is that Action Comores antenne Anjouan has hired a Roost Monitoring Program coordinator, Ishaka Saïd, to regularly visit and retrain monitors, and to coordinate the field activities of the monitoring program. Projet Biodiversité, Terre et Faune, and Conservation International-Madagascar have provided funding in the recent past. Action Comores International, Durrell Wildlife, and international researchers have provided field gear for roost monitors. In addition, Action Comores – International has provided detailed monitoring reports to the Comoros in 2004 and 2006 (Action Comores 2004, 2006), and has begun more in-depth analysis of the monitoring data. One of the primary goals of the current analysis is to determine the natural variability in the population and observer error to facilitate future detection of population trends. Results will be summarized, sent to the Comoros partners, and submitted to a peer-reviewed journal.

More work remains to be done to improve the program. Roost monitors were not paid at all for eighteen months in 2004 and 2005, and again for several months during 2006 and 2007. Further, the future funding of the program remains uncertain. Roost monitors are still short on field gear and training necessary for completing their observations. Some data collected on Moheli between 2001 and 2005 was not archived on Moheli and was lost in transfer from Moheli to Anjouan. Compilation

of data on Moheli and Anjouan remains inefficient, and transfer of data to Action Comores International is accomplished only sporadically. These problems should be tackled through direct targeted interventions.

Nonetheless, despite these challenges, the monitoring program has continued to collect quality data on Livingstone's flying fox for 15 years, and is now one of the longest-running population monitoring programs in a developing country. In addition to the extremely useful population data that has been collected, a number of additional indirect benefits have resulted from the population monitoring program. First, the involvement of local people in the program has increased awareness considerably amongst local communities about the existence of Livingstone's flying fox. As roost monitors learn more about the ecology of the species through their own observations and the training provided by the population monitoring program coordinator, they have shared this understanding with others in the community, resulting in a higher baseline understanding of Livingstone's flying fox and their ecological importance. This informal environmental education effort may result in broader support for future conservation efforts, and has already fed back into the population monitoring program through the discovery and reporting of new roosts – the number of known roost sites has increased from two roosts in 1990 (Carroll & Thorpe 1991) to 23 in 2006. The majority of these new roost sites have been identified with the assistance of local people. Finally, the population monitoring program has developed into an informal network by which information can be quickly passed throughout the island. This network is already being exploited for other conservation purposes, which in turn builds the capacities of roost monitors and Ulanga groups.

Broad Aim D: Track population trends and improve estimation of the population size and conservation status of Livingstone's flying fox

Population Monitoring Program objectives and actions

D.1. Increase the contributions of the Population Monitoring Program to habitat protection and environmental education.
- D.1.a. Training of roost monitors and Ulanga associations in community outreach.
- D.1.b. Training of roost monitors and Ulanga associations in diverse data collection methods, and the planning, establishment, and monitoring of protected areas.
- D.1.c. Frequent organization of community education meetings by each roost monitor and / or Ulanga association.
- D.1.d. Frequent analysis of data from the Population Monitoring Program, and use of the results to inform habitat protection efforts.

D.2. Continue the Population Monitoring Program.
- D.2.a. Financial support for roost monitors and the coordinator of the Population Monitoring Program.
- D.2.b. Regular monitoring at all known roosts, once per month by the roost monitors and twice per year by teams comprised of the local roost monitor and members of the local Ulanga village association.
- D.2.c. Greater involvement of landowners where roosts fall on private land, and local authorities where roosts fall on communal land.
- D.2.d. Creation of a stable funding source and an emergency fund for the Population Monitoring Program.

D.3. Improve the efficiency of collating and analyzing data from the Population Monitoring Program.
- D.3.a. Training of the coordinator of the Population Monitoring Program in the use of Action Comores Anjouan's motorcycle, and provision of travel expenses to visit roost monitors and compile monitoring data.
- D.3.b. Provision of financial resources for sending data between Moheli and Anjouan.
- D.3.c. Acquisition of computer resources needed to send the data electronically from Moheli and Anjouan to Action Comores International every three months.
- D.3.d. Capacity-building of Action Comores Anjouan personnel in computer skills.
- D.3.e. Recruitment of assistance for data entry.

D.4. Improve the reliability of data archiving for the Population Monitoring Program.

D.4.a. Monthly archiving of hard copies of data for each site by that site's monitor.
D.4.b. Monthly archiving of hard copies of all Moheli data on Moheli.
D.4.c. Monthly archiving of hard copies of all data from both islands by Action Comores Anjouan.
D.4.d. Archiving every three months of electronic copies of all data from both islands by Action Comores Anjouan and by Action Comores International.

D.5. Improve the accuracy of data collection to permit the detection of changes of 25% in the size of the bat population over a five-year period.
D.5.a. Acquisition of high-quality waterproof binoculars and other field gear for each roost monitor and for the coordinator of the Population Monitoring Program.
D.5.b. Visit to all roost sites, once per year or more frequently, by the coordinator of the Population Monitoring Program for quality control of data and training of roost monitors.
D.5.c. Capacity-building of the coordinator of the Population Monitoring Program in research techniques, program management, data compilation, teaching techniques, and computer skills.
D.5.d. Regular capacity-building of roost monitors and Ulanga associations on bat counting techniques, maintenance and use of field gear, research methods, and species identification.
D.5.e. Study of means to improve data collection and analysis to increase the accuracy of results.

D.6. Regularly inform the Comorian people as well as the Advisory Committee on Science and Conservation of Livingstone's Flying Fox on the status of the wild Livingstone's flying fox population.
D.6.a. Preparation and dissemination in the Comoros by Action Comores International of brief annual reports on the wild population of Livingstone's flying fox.
D.6.b. Preparation and dissemination in the Comoros by Action Comores International of more detailed reports every three years on the wild population of Livingstone's flying fox.
D.6.c. Capacity-building of Action Comores Anjouan personnel in statistics.

D.7. Study the feasibility of expanding the Population Monitoring Program.
D.7.a. Study of the feasibility of using the network of roost monitors and Ulanga associations to monitor forest reserves.
D.7.b. Study of the feasibility of using the network of roost monitors and Ulanga associations to monitor other species, such as bird and tree diversity.
D.7.c. Study of the feasibility of using the network of roost monitors and Ulanga associations to monitor human impact on Livingstone's flying fox and its roosting and foraging habitat.

D.8. Improve this Population Monitoring Program and plan future actions.
D.8.a. Evaluation of the contribution of this Population Monitoring Program to the conservation of Livingstone's flying fox and its rainforest habitat, and to Comorian biodiversity and the Comorian people.
D.8.b. Development of a plan to increase the involvement of stakeholders in monitoring efforts.
D.8.c. Development of a long-term plan to increase the reliability and accuracy of the Population Monitoring Program.

E. Ecological Research

Ecological research on Livingstone's flying fox has contributed much to conservation of the species. The basic ecology of Livingstone's flying fox was uncovered during initial field studies (Waters *et al.* 1988; Carroll & Thorpe 1991; Action Comores 1992, 1993, 1994, 1997). Locating roost sites (Action Comores 1992, 2006, Clark *et al.* 1997, Granek 2002) and determining roost site characteristics (Granek 2002), has enabled targeting of roosts for priority protection. Identifying tree species used as foraging resources (Trewhella *et al.* 2001, Sewall 2002) and their relative importance (Sewall 2002) has enabled targeting of tree species and areas of forest for priority protection. However, there is much more to learn about roosting and foraging habitat. Several other topics, such as behavior, have scarcely been studied. These gaps in our understanding hinder the development of specific management goals.

Ecological research was recommended in *Old World Fruit Bats: An Action Plan for their Conservation* (Mickleburgh *et al.* 1992) and the IUCN *Species Action Plan* (1994). Many important scientific goals exist for the study of Livingstone's flying fox, but of particular importance for this conservation plan are those studies that contribute directly to conservation of Livingstone's flying fox and its habitat. Conservation activities can be more clearly targeted in the future if there is an investment in further conservation-oriented applied ecological research now. There is an important need, therefore, for continued ecological research in support of the conservation of Livingstone's flying fox and its habitat.

Research to improve roost site conservation

Conservation of Livingstone's flying fox roost sites could be improved if the bats' use of roosts were better understood. Preliminary observations indicate that the bats do not simply rest statically in one roost tree all the time, but rather, they move within the tree, sometimes to neighboring trees, and on occasion farther away (I. Saïd, pers. obs., E. Granek, unpublished data., J. Hawes & B. Sewall unpublished data). At one roost, sexual segregation has been observed (J. Davies, pers. comm., Action Comores 1999), and colonies are more aggregated at roost sites during the wet season than the dry season (Granek 2002). This means that the simple conservation of one individual key roost tree will be insufficient to meet bats' roosting needs. A more dynamic understanding of roost site use that incorporates this daily and seasonal variation could enable a better understanding of how much roost habitat must be protected, and which elements of roosting habitat are most critical. Such studies may be aided by radiotracking or other methods for following individuals. This may enable better targeting of lands for roost habitat protection. Some study has been conducted on bat thermoregulation at roost sites (Hawes 2002, J. Hawes & B. Sewall unpublished data); but further study would shed more light on these issues. And little is known about maternity roosting in this species.

Livingstone's flying fox uses forested areas for primary roosting habitat. Some roosts have persisted after human impacts, while other roosts have been abandoned (see part II.A. Habitat Protection). With human population growth and expansion into previously remote forested areas comes the potential for increased interactions between bats and people at roost sites. How much and what kinds of human use will the bats tolerate before abandoning an otherwise suitable roost site? Which human uses will not cause abandonment, but will still negatively impact bats' survival or reproduction? How may human uses affect tree recruitment and forest regeneration? Such questions might be answered by a study of how proximity, amount, and type of human land use affect Livingstone's flying fox roosts. The results of such a study would facilitate the development of management rules for protected areas that balance the needs of the bats and local people.

Research to target foraging habitat conservation

Livingstone's flying fox uses native forests for its primary foraging habitat (Carroll & Thorpe 1991, Action Comores 1992, Action Comores 1997, Trewhella *et al*. 2001, Sewall 2002), and Livingstone's flying fox's survival will depend largely upon the success of forest conservation. Yet Livingstone's flying fox also visits suitable fruiting trees located within mixed agricultural lands (Young *et al.* 1993, Sewall 2002, B. Sewall unpublished data). This observation suggests that the

retention of the bats' preferred tree species in agricultural lands could be an integral part of the overall conservation strategy (Sewall 2002). How much human interaction will bats tolerate at foraging sites? What kinds of agricultural practices are bat-friendly? Does foraging within the agricultural matrix incur greater costs through increased search time? As native forest is increasingly removed, fragmented, and degraded throughout Anjouan and Moheli, long-term goals for the amount of forest to protect, management practices in those protected areas, and conservation on private lands will increasingly depend on the answers to these questions.

Studies of Livingstone's flying fox foraging have identified important fruit and flower resources (Trewhella *et al.* 2001, Sewall 2002) and indicated that between-season variation in availability is important (Sewall 2002). However, much remains to be learned about infrequently used foraging resources and within-season variation in diet. Valuable information could be gained about the seasonal availability and nutritional quality of food resources from a continuous year-round study of Livingstone's flying fox's foraging ecology. Study of movements between roosts and feeding sites and of the distances that bats fly to forage has been limited, so the foraging area needed by individual bats, bat colonies, and the entire bat population on each island is poorly understood. More information is needed about the role of Livingstone's flying fox in the ecology of its forest habitat through pollination and seed dispersal. Studies addressing these questions could improve targeting of critical foraging habitat for protection, lead to legal protection of specific tree species, provide farmers, landowners, and foresters with guidelines of tree species to favor in management and reforestation activities, and improve nutrition for captive bat colonies.

Research to track and understand deforestation and other threats

Available maps of forest cover in the Comoros Islands are years out of date. Even the most recent maps of Anjouan and Moheli (IGN 1995a & b) rely on decades-older surveys of topography, land use, and ground cover. With the rapid and sustained deforestation of Anjouan and Moheli, land use and vegetation have changed dramatically. Of the forest areas indicated on these maps, it is likely that only a small fraction actually remains forested (I. Saïd, E. Granek, & B. Sewall pers. obs.). Without more recent information on how much Livingstone's flying fox habitat remains, where it is located, and how it is distributed on Anjouan and Moheli, conservation planning will be extremely difficult. Up-to-date aerial or satellite survey work on the distribution of vegetation types in the Union of the Comoros, coupled with appropriate ground-truthing studies, could provide this needed information.

The historical population size of Livingstone's flying fox is unknown, but it is likely that the population has sharply declined over time due to human modification of land and other impacts. Further genetic work on the species might help determine long-term historical population size, and thus indicate the extent of population decline over time.

Other, nonhuman species may also be contributing to Livingstone's flying fox's endangerment. Other Comorian vertebrate frugivores use some of the same food resources (sometimes simultaneously) as Livingstone's flying fox (Sewall 2002, Sewall *et al.* 2003, B. Sewall unpublished data), and Comorian lemurs almost certainly represent a recent, anthropogenic introduction from Madagascar (A. Yoder, pers. comm.). Now that many native fruiting trees have been cut, are other frugivore species negatively impacting Livingstone's flying fox through resource competition? It is currently impossible to say (Rogers 1998), but a study detailing interactions between Livingstone's flying fox and other members of the vertebrate frugivore guild might clarify whether this is a management issue that should be addressed to ensure the bats' persistence.

In addition, accurate accounting of conservation status and threats will help direct the appropriate amount of resources to counter the most important threats. Ranking threats to Livingstone's flying fox by relative importance, and identifying parameters contributing to uncertainty in the evaluation of its conservation status would enable more accurate targeting of population monitoring program efforts, and allow for updating the IUCN Red List conservation status.

Research on behavior and population dynamics

Little is known about the population structure and dynamics of Livingstone's flying fox, though these factors have important implications for managing the population as a whole. Bat

movement between roosts and between islands has not yet been explored. Genetic work on population structure (e.g., within- and between-island variation) could facilitate management planning by identifying subpopulations or other management units for the species.

Although there have been observations on the timing of reproduction (Trewhella *et al*. 1995) little is known about the age structure of the population or main mortality factors. The mating strategy and social organization of wild Livingstone's flying foxes is not well studied, although in captivity social organization appears similar to that of captive Rodrigues flying foxes *Pteropus rodricensis*, with a dominant male defending a harem of females, and subordinate males and juveniles forming a separate sub-group (Herron 1993; Courts1996a, 1996b). There is a dearth of information on maternal roosting behavior, which may be an important part of reproduction and roost site designation. Further studies on the reproductive behavior could facilitate management planning by clarifying the population dynamics of the species. Finally, the village of Ouallah-Miréreni on Moheli maintains the Hassera-Ndrengé roost site with low human disturbance for scientific research purposes; this setting may facilitate the study of roosting behavior in the wild.

Research to develop and improve conservation and management techniques

Protected area management will require a variety of new information and techniques. In addition to the points mentioned above, knowledge of the phenology of tree species providing fruit and flower resources to Livingstone's flying fox will be important in management efforts to ensure a year-round supply of food resources for the bats. And reforestation with native tree species will be dependent upon the development of techniques to germinate and propagate those species.

Research on captive populations is also important to improving conservation and management techniques. Long-term success in captive breeding will require new information and techniques in addition to the nutrition and foraging studies mentioned above. Ongoing paternity analyses with genetic markers could help determine parentage in captive colonies, and permit pair management to reduce loss of genetic diversity. Behavioral research on aggression in captivity under different management regimes will help ensure long-term viability of captive colonies. An evaluation of accommodations and husbandry practices could lead to changes in captive colony management that would enable bats to express a more comprehensive repertoire of natural foraging behaviors, encourage flight, and improve physical condition. A review of the feasibility and successes of other flying fox reintroduction programs could benefit any eventual reintroduction of captive Livingstone's flying fox. Finally, research integrating a study of the ecology of Livingstone's flying fox with social factors in nearby villages could clarify which conservation activities will have the greatest likelihood of benefiting bats, their habitat, and local people.

Integrating research and conservation

It is important that scientists and conservation actors remain engaged so that (1) conservation is based upon the most accurate and up-to-date information available, and (2) scientists conduct research that is useful for the conservation program. To address these two points, a new committee should be established, the Advisory Committee on Science and Conservation of Livingstone's flying fox (ACSC). This organization should be linked to the Species Survival Commission's Chiroptera Specialist Group (SSC-CSG) of the IUCN. This committee should be responsible for providing scientific advice on the research and conservation needs for Livingstone's flying fox, and on conservation methods for those on the ground in the Union of the Comoros. The committee should also encourage scientists to conduct research in the Comoros Islands that corresponds to priority conservation needs for Livingstone's flying fox and its habitat. The committee should monitor ecological research on other fruit bat species and social science research on community-based conservation to collect information that would benefit conservation efforts for Livingstone's flying fox and its habitat. Finally, coordination between research projects should be done through the ACSC.

Capacity-development

The lack of trained ecologists in the Union of the Comoros is a serious problem for the long-term continuity of any ecological research program. Capacity-development could best be

accomplished by involving Comorians directly in all aspects of the scientific research process. Progress can be made toward the long-term goal of establishing a cadre of highly trained Comorian ecologists, conservation biologists, and conservation practitioners by providing opportunities to fund the study of secondary and post-secondary level students in the biological sciences, facilitating their participation in scientific research, and assisting them in designing and running independent research projects.

Broad Aim E: Increase scientific understanding of the ecology and biology of Livingstone's flying fox.

Ecological Research Program objectives and actions

E.1. Develop local capacity for scientific research.
- E.1.a. Development of opportunities for the participation of Comorian students in research.
- E.1.b. In-depth training of Comorian students in ecology.
- E.1.c. Provision of opportunities for Comorian post-secondary students to participate in field research.
- E.1.d. Provision of opportunities for independent research and training for Comorian secondary and post-secondary students interested in scientific research and conservation of Livingstone's flying fox.
- E.1.e. Development of a competitive scholarship program to support Comorian students enrolled in a university in a field related to ecology or conservation of Livingstone's flying fox.
- E.1.f. Provision of competitive research grants for Comorian students for scientific research on Livingstone's flying fox.
- E.1.g. Availability of a full-time ecology specialist in the Comoros for training technicians.

E.2. Contribute information to improve roost site conservation.
- E.2.a. Completion of studies of daily, within-season, and seasonal variation in roost site use, behavior and population dynamics, and human impact on roosting behavior.
- E.2.b. Provision of research grants for field research that will improve the conservation of Livingstone's flying fox.

E.3. Contribute information to improve foraging site conservation.
- E.3.a. Completion of studies on foraging behavior, nutrition, and human impact on foraging sites.
- E.3.b. Identification of tree species and foraging sites critical to Livingstone's flying fox throughout the year.
- E.3.c. Provision of research grants for field research that will improve the conservation of Livingstone's flying fox.

E.4. Contribute information to improve conservation planning.
- E.4.a. Completion of studies of vegetation and land use, intra-guild competition, and factors affecting bat conservation status.
- E.4.b. Promotion of scientific research linked to the conservation of Livingstone's flying fox.
- E.4.c. Dissemination of results of scientific studies and published articles to universities, non-governmental organizations, and documentation centers in the Comoros.
- E.4.d. Submission of summaries of research results to *Ya Mkobe*, to *Habari za Ulanga*, and to other Comorian scientific and environmental publications.

E.5. Better integrate research and conservation.
- E.5.a. Establishment of the Advisory Committee on Science and Conservation of Livingstone's Flying Fox.

E.6. Develop new techniques and information to facilitate implementation of forest management and husbandry of captive Livingstone's flying fox populations.
- E.6.a. Completion of studies on forest restoration, germination of seeds of native trees, and raising of native tree seedlings in tree nurseries.
- E.6.b. Completion of genetic analyses and studies on the mating system of the species.

E.7. Improve this Ecological Research Program and plan future actions.

E.7.a. Evaluation of the contribution of this Ecological Research Program to the conservation of Livingstone's flying fox and its rainforest habitat, and to Comorian biodiversity and the Comorian people.

E.7.b. Development of a long-term plan to provide additional training and offer more research opportunities to Comorians.

F. Ex-Situ Breeding

Ex situ captive breeding programs (breeding outside the natural habitat) have a number of functions including:

1. Increasing opportunities to raise funds for conservation and research purposes through grants, donations, or other means,
2. Raising awareness of a species' plight in the wild, increasing interest in the species, and generally helping people understand threats to biodiversity, all through environmental education focused around the captive population
3. Maintaining the species in captivity if there is a risk of extinction in the wild (an insurance population),
4. Providing animals for reintroduction, should that ever be necessary, due to either extinction or near extinction of the wild population, and
5. Providing an opportunity to advance scientific understanding of some aspects of the biology of the species, since many observations that can be made in captivity are impossible to undertake in field studies.

While *in-situ* (within natural habitat) conservation should be the aim for critically endangered species, captive breeding programs may sometimes be a viable short-term option to reduce risk of extinction. In short, a well-managed captive colony of an endangered species can have beneficial impacts consistent with conservation aims (IUDZG/CBSG (IUCN/SSC) 1993). The ex-situ conservation breeding program for the Livingstone's flying fox fulfils all of these functions, and should be continued and enhanced.

Conservation breeding program for Livingstone's flying fox: establishment and early accomplishments

After field expeditions to the Comoros Islands concluded that few individuals remained in the wild (Cheke & Dahl 1981, Waters *et al*. 1988, Carroll & Thorpe 1991), and the publication *Old World Fruit Bats: An Action Plan for their Conservation* (Mickleburgh *et al.* 1992) strongly recommended captive breeding of Livingstone's flying fox, efforts were undertaken to establish captive colonies. A coalition of groups including Durrell (then known as Jersey Wildlife Preservation Trust) and Action Comores-International signed an accord with the government of the Union of the Comoros (then known as the République Fédérale Islamique des Comores) to capture wild individuals for a British Isles-based captive breeding program in 1992. According to the agreement, these individuals and all their descendants remain the property of the Government of the Union of the Comoros. The program was modeled on the captive breeding program for the Rodrigues fruit bat (*Pteropus rodricensis*), which was initiated in 1976 with 18 founders (Carroll 1988; Mace and Carroll 1995) and now houses in excess of 660 bats in 33 institutions worldwide (M. Brayshaw, pers. comm.).

Between 1990 and 1995, when a minimum estimate of the wild population of *P. livingstonii* was 152 individuals (Action Comores 1997), four expeditions from the United Kingdom visited the island of Anjouan, and captured a total of 10 male and seven female bats (Young *et al*. 1993; Trewhella *et al*. 1995; Clark *et al*. 1997). The 17 captured bats, along with two wild-conceived young born in captivity, formed the founder population for the captive colonies. Since the last import of bats from the wild in 1995, the captive population has increased in size at a rate of 10.12% per year (Figure 4). By the end of 2005, the population (housed in four separate colonies at Durrell Wildlife and Bristol Zoo Gardens) had reached 48 individuals, comprising 33 males and 15 females, with 11 of the original wild-caught bats surviving (W. Masefield, unpublished data). The reasons for this strong sex bias is unknown; understanding them would be of particular interest given the similar male-biased sex ratio found in every capture expedition to date – such a strong sex bias in mammals is unusual.

Figure 4a. *Ex-situ* population changes. Occurrences of Births, Deaths, Neonates not Surviving the First Three Days (DNS), Imports from the Wild, and Total Population since the Initiation of the Breeding Programme (data current to December 2005).

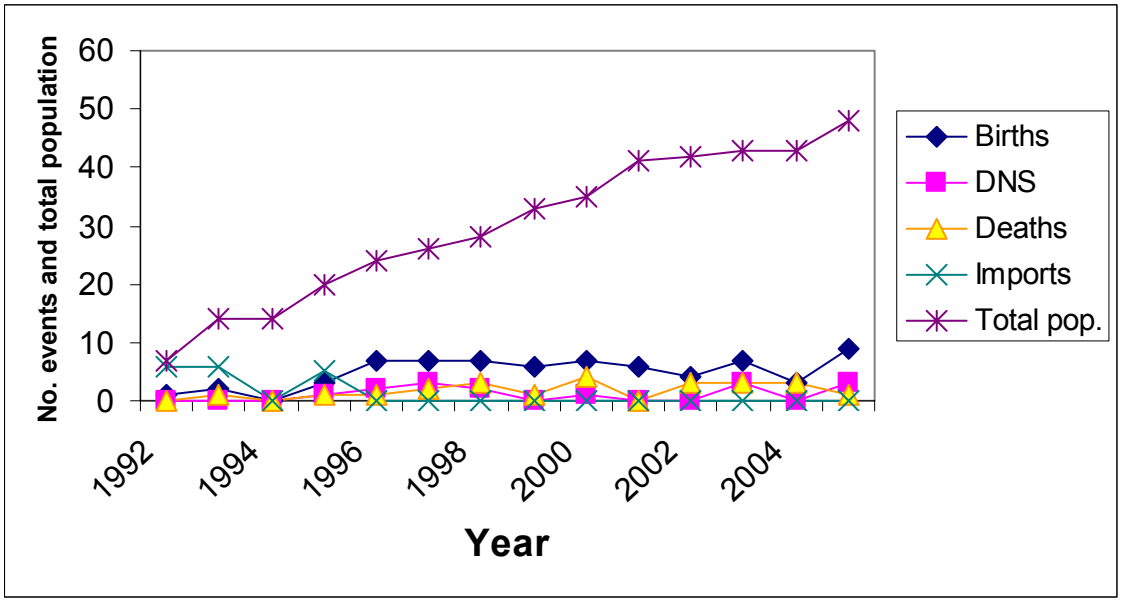


Figure 4b. Age-Specific Mortality

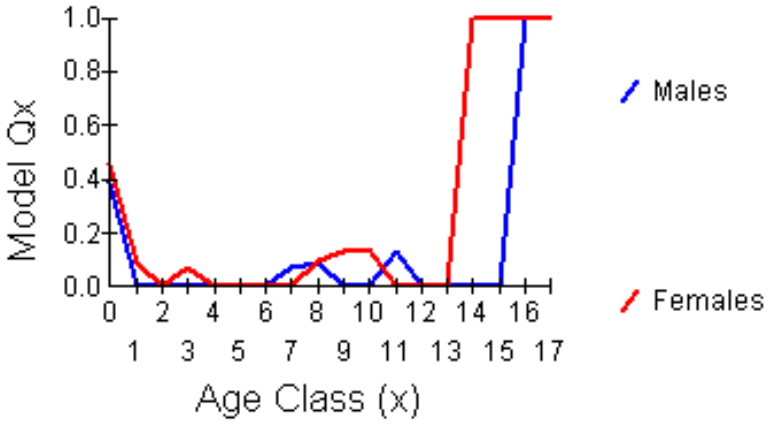
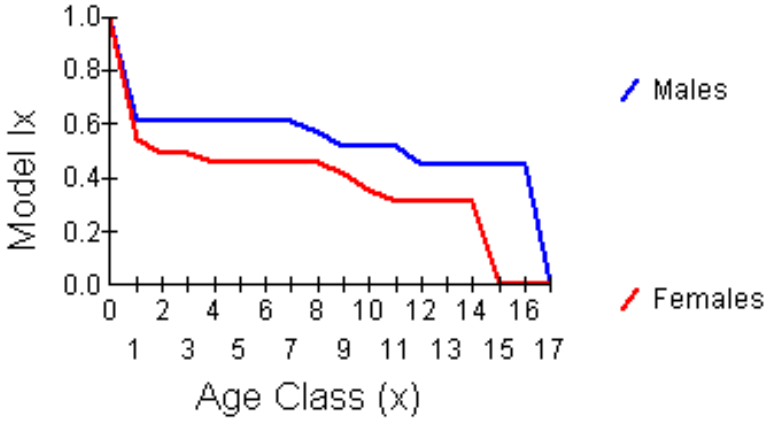


Figure 4c. Age-Specific Survivorship



The captive colonies are valuable in several ways. Daily talks about Livingstone's flying fox are given to zoo visitors by volunteers from April to September at Bristol Zoo and from June to October by Durrell education staff. These talks reach an estimated audience of more than 20,000 people per year. Secondly, at both Durrell and Bristol Zoo Gardens, public exposure to the Livingstone's flying fox captive colonies has benefited conservation fundraising, in addition to publications and other media exposure highlighting their plight in the wild. Finally, a number of interesting scientific studies on behavior, social interactions, male territoriality, infant development, nutrition and flight muscle density have been conducted at Durrell and published (e.g., Courts 1998, 1999, Masefield 1999, Courts & Feistner 2000, Ramsay *et al*. in prep).

Present status of captive colonies

In the short term, the greatest threat to captive individuals and the greatest concerns with their potential reintroduction are disease and physiological and behavioral changes induced by captivity (Fowler 1993, Kleiman 1996). Specific measures, such as isolation from other species, are used to minimize threats to Livingstone's flying fox, and to date captive colonies have remained disease-free. Regular disease surveillance programs are also undertaken at both Jersey Zoo and Bristol Zoo Gardens to provide an early warning in case of disease transmission to the captive colonies.

Studies have been conducted on the captive diet to combat excessive weight gain observed in earlier captive colonies, which may have resulted from inadequate space (e.g. Courts, 1997, 1999; Paynter, 2001), and enrichment work is ongoing to encourage foraging behavior and flight. Enclosures at both Jersey and Bristol have been significantly expanded, and fitness of captive bats has improved as a result. Planning is also underway to further expand the size of one of the Jersey enclosures. This has increased opportunities for flight as well as preparing for increases in the captive population (Figure 5).

Figures 5a and b. Flying captive bats. Visitors marvelling at the bats flying in one of the Durrell enclosures Photos by Richard Wainwright

A European Studbook (ESB) has recently been compiled for Livingstone's flying fox (Masefield 2003, 2004, 2005) - only the second for a bat species. The maintenance of a studbook for the species will enable a genetically healthy population to flourish, and will be managed and updated by Will Masefield, the official Studbook Keeper (see contact information at the end of this plan). From a genetic perspective, the most significant short-term threat to small captive populations may come from inbreeding depression (although this is not yet apparent for this species, nor for *P. rodricensis*, in captivity), the decline in individual fitness from mating among close relatives. This potential problem may be mitigated through natural dominance changes within the group, or by management techniques whereby breeding males are rotated after a certain length of time with females. Analysis of DNA will be an essential tool for the future of the breeding program, as definite knowledge of paternity will be necessary in order to maximize retention of genetic diversity.

When managing small populations, there will always be concerns that small population size and mating among close relatives may result in the loss of adaptive genetic variation (Rodríguez-Clark 2002). In colonial species, pedigree relationships can be difficult to determine and mating patterns can be difficult to influence (Princeé, 1995), but with evidence of paternity (acquired through

analysis of DNA), the captive populations of Livingstone's flying fox will be managed to minimise loss of variation to retain 90% over 100 years, in order to avoid problems such as these.

A new partnership between these zoos and the Estacion Biologica de Doñana will also enable an assessment of the genetic structure of populations on Anjouan and Moheli, and studies are currently underway to extract DNA through the non-invasive techniques of faeces and ejecta pellet collection.

Arrangements are being made now for Chester Zoo to join Bristol and Durrell as a host for captive Livingstone's flying fox individuals, to help house the expanding captive population. There may be a need in the future for additional institutions to take on a bachelor group of Livingstone's flying fox, but the current host institutions will only consider one that can supply them with the space and year-round warmth that this species needs in addition to a commitment to support in-situ conservation efforts in the Comores.

Next steps for the ex-situ conservation program

Additional institutions are expected to be involved in the near future, based on interest expressed to date. Therefore, space limitations should not prevent attainment of genetic and demographic goals of the captive breeding program.

On the basis of information from genetic analysis, the studbook, ongoing research, and the review of management, the Studbook Keeper will provide management guidelines and other recommendations to all institutions participating in the breeding program. The European Studbook will in time form the basis of a full European Endangered Species Program, to be developed by Durrell. In this program, at least one population will be a bachelor group to act as a reservoir and to maintain an appropriate sex ratio in the breeding groups.

If genetic diversity drops considerably in captivity, then further changes to the management regime may be necessary. Another possible remedy to genetic problems is importation of new individuals from the wild. However, such an action would risk further depleting the wild population, and for this reason would only be undertaken after very careful consideration of conservation implications for the species and permission from the government of the Union of Comoros. A further option (if concerns of disease transmission and behavioral and physiological changes can be mitigated) may be the adoption of a metapopulation management strategy wherein some individuals from the captive population are released to the wild, while a smaller number of wild individuals are captured and brought into the captive population (Foose *et al*. 1995).

Broad Aim F: Maintain a captive population with the potential for future reintroduction into the wild, while increasing opportunities for scientific research, environmental education, and fund-raising.

Ex-Situ Breeding Program objectives and actions

F.1. Increase captive population size to exceed 50 individuals by end of 2007 and 65 by the end of 2010, and to attain demographic stability in the captive population.
- F.1.a. Continuation of the intensive breeding of the first generation.
- F.1.b. Increase in the number of host institutions.

F.2. Raise awareness amongst people outside the Comoros about the existence of these bats and the threats they face, and the importance of biodiversity in the Comoros.
- F.2.a. Continuation of the use captive colonies as a focal point for environmental education of zoo visitors about the ecology and conservation of Livingstone's flying fox.

F.3. Raise funds for scientific research linked to sound management of the species in captivity.
- F.3.a. Use of the captive colonies as a focal point for fund-raising to support scientific studies, particularly on the genetics and mating system of the species.

F.4. Raise funds for the conservation of Livingstone's flying fox and its habitat in the wild through work with local communities and Comorian authorities.
- F.4.a. Use of the captive colonies as a focal point for fund-raising to support conservation of Livingstone's flying fox and its habitat.
- F.4.b. Implementation of a program to provide annual financial support of Action Comores Anjouan by zoos holding Livingstone's flying fox individuals in captivity.

F.5. Maximize opportunities for scientific research of conservation value on the captive animals.
    F.5.a. Encouragement of scientific research on the captive population, especially for studies important for conservation but not feasible on the wild population, such as behavioral, demographic, or nutritional research.
F.6. Maintain the physical condition and behavioral integrity of individual animals and the population as a whole, both for their educational and scientific value, and in case a severe decline in the wild population necessitates reintroduction.
    F.6.a. Continuation of the development of quality accommodations in captivity to maintain sufficient space for flights by all the colonies in captivity.
    F.6.b. Continuation of the development of quality husbandry practices to enable bats to express a more comprehensive repertoire of natural foraging behaviors, to encourage flight, and to maintain physical condition.
F.7. Provide feedback annually to the Government and people of the Union of Comoros as well as the Advisory Committee on Science and Conservation of Livingstone's Flying Fox on the status of the captive breeding colonies.
    F.7.a. Preparation of and dissemination in the Comoros by the zoos of annual reports on the state of colonies of Livingstone's flying fox in captivity.
F.8. Minimize inbreeding and maintain as much of the captive population's original genetic diversity as possible, managing the captive population with the aim of retaining 90% of the original heterozygosity over 100 years in line with IUCN Captive Breeding Specialist Group (IUCN-CBSG) recommendations.
    F.8.a. Maintenance of a European Studbook for the population of Livingstone's flying fox in captivity.
    F.8.b. Management of the population to prevent inbreeding depression and minimize loss of genetic diversity. Transfer of individuals between institutions if necessary.
F.9. Improve this Ex-Situ Breeding Program and plan future actions.
    F.9.a. Evaluation of the contribution of this Ex-Situ Breeding Program to the conservation of Livingstone's flying fox and its rainforest habitat, and to Comorian biodiversity and the Comorian people.
    F.9.b. Development of a Population Management Plan that corresponds with European Association of Zoos (EAZA) or American Zoo Association (AZA) guidelines, to formalize objectives and guide future management practice.
    F.9.c. Development of a long-term plan to manage a self-sustaining, genetically viable captive population of Livingstone's flying fox.

G. Conservation Partnerships

In order to keep this *Conservation Action Plan* focused on direct threats to Livingstone's flying fox and its habitat, sections A-F of the Conservation Strategy have not addressed broad conservation and development issues such as rural poverty, population growth, and lack of access to health care and education. Yet these factors increase pressure on native forests and limit the opportunities local people have to support themselves in sustainable ways, and thus will have a strong impact on the success of any conservation initiatives for Livingstone's flying fox.

For example, six times as many people live on Moheli now than did in 1900 (Moulaert 1998), and Anjouan appears to have undergone an even faster rate of population increase. The current rate of human population growth – now at 2.8% annually (Birdsall & Fukuda-Parr 2002) – means that twice as many people must be supported in the same land area every 25 years. In addition, the current average rural income in the Union of the Comoros is only about one dollar (USD) a day (World Resources Institute 1993, World Bank Group 2002). Historically, the need to provide more land to young people and to increase income has been resolved by converting more native forest to agricultural land, but now little forest remains, and what does remain is critical to biodiversity conservation and to maintaining the ecological services upon which Comorians depend. Further forest clearing threatens not only Comorian biodiversity, but the Comorian people's future. But local people suffer from having few economic alternatives, and have immediate needs for more resources, and so forest clearing has not slowed.

This situation poses a clear threat to Livingstone's flying fox and its habitat, and failure to address it would, in the long run, undermine the rest of the conservation plan. However, fully addressing any one of these underlying indirect issues is beyond the limited scope of this conservation plan, and may require different sets of expertise from those required for the rest of the plan. The formation of partnerships with other government agencies and non-governmental organizations may help conservation efforts remain focused on direct threats to Livingstone's flying fox and its habitat, while also supporting the efforts of other organizations to address the broader underlying issues, and facilitating the sharing of resources and diverse expertise. A high priority for effective conservation, therefore, is the formation of such partnerships to address these broader threats.

Nature of the Partnerships

To improve chances of success of the Livingstone's flying fox conservation strategy, collaborations should be initiated with partner organizations or local residents sharing common goals. For example, the Livingstone's flying fox conservation effort could assist the organization of outreach meetings by agricultural or health extension services in remote villages near Livingstone's flying fox roost sites through the network of Action Comores antenne Anjouan roost monitors and Ulanga village associations. These agriculture and health extension services, in turn, could provide training, skills, information, and resources to local people in ways that help them reduce their impact on the forest. A list of potential Comorian and international partner organizations is included in the Introduction.

Common goals should be identified with local residents and the partner organization. For example, provision of sufficient quantities of clean water is an essential element of most public health programs, erosion control is essential in agriculture, and riparian corridor protection is essential to many conservation efforts. Conservation of Livingstone's flying fox habitat can greatly benefit these efforts, since the bat's montane forest habitat is also essential to controlling topsoil erosion and maintaining permanent rivers. Of the 45 permanent rivers on Anjouan in 1925 (Hunter *et al.* 1992), only 12 were flowing year-round in 1989 (E. Granek, pers. obs.) and only 6 of these were still flowing year-round in 2002 (I. Saïd, pers. obs.), mostly due to deforestation at progressively higher elevations. The presence of rivers and riparian forest areas is also correlated with presence of Livingstone's flying fox roost sites (Granek 2002). Partnerships between organizations focused on providing clean water, reducing erosion, or conserving watersheds or riparian areas, and organizations focused on Livingstone's flying fox could increase the benefit to both the Comorian people and to conservation. Such partnerships may enable each group to attain its goals more effectively working together than by working independently.

Sustainable development through small-scale ecotourism

Ecotourism can provide motivation to protect an endangered species by offering an economic benefit from the protection of the species. The uniqueness and charisma of Livingstone's flying fox have the potential to attract ecotourists, and therefore present an opportunity for small-scale ecotourism development on Moheli and Anjouan.

An ecotourism effort is already underway in the village of Ouallah-Miréreni on Moheli. This small-scale effort follows the model of the successful Itsamia sea turtle ecotourism project. Four bungalows and a '*Maison de Livingstone*' tourist information center have been constructed by the community, at the initiative of the village association with funding support from Projet Biodiversité, European Development Funds, and other donors interested in supporting communities with income generating activities aimed at reducing pressure on natural resources. The community provided a monetary and in-kind contribution; and donors provided a grant and a loan, and the latter was gradually paid back by the community. The income from the bungalows and from the guided tours to the Kidogo-Basse roost goes into maintenance of the facilities as well as to general community development projects (C.M. Iboura, pers. comm.).

Although relatively few tourists visit Moheli (c. 300-400 per year), the majority being visitors from Grand Comore, Mayotte and Reunion, many of these visit both the turtle and the Livingstone ecotourism initiatives - the roosts at Ouallah-Miréreni received about 15 tourists a month in 2001 and the number has increased since then. Some only visit briefly, but many stay overnight at the bungalows, and also pay for meals, taxi fares, or souvenir items, contributing to local revenue generation, much of which is shared at a community level. The amount of money generated is small, but it provides a welcome boost to the local economy, and has led to a positive change in local attitudes toward the bats (C.M. Iboura, pers. comm.).

Ecotourist activities on Anjouan are less developed. From April to June, Action Comores antenne Anjouan personnel bring a few ecotourists (about 5- 10 a month) to the Mpampafumaju seasonal feeding site near the village of Sangani. Action Comores antenne Anjouan and Action Comores - International have also identified the Bandra roost site near Mromadji as a possible ecotourist destination.

Potential exists to expand ecotourism on both islands. On Moheli, recent construction of bungalows in two towns neighboring Ouallah-Miréreni, Ouallah 2 and Miringoni, may provide additional opportunities to bring tourists to visit bats at the Kidogo-Basse roost. Most tourists visiting Moheli or Anjouan, however, are still unaware of the presence of Livingstone's flying fox or of opportunities to see it. Ecotourist opportunities may also attract tourists living on or visiting Mayotte or Grande Comore, or may entice backpackers visiting Madagascar or eastern mainland Africa. Future efforts should be informed by the Projet Biodiversité Draft Ecotourism Development Plan.

It is important to note that poverty, lack of infrastructure, and a history of political instability in the Union of the Comoros make a large-scale ecotourism industry unlikely to be sustainable in the near future. Small-scale community-based efforts are likely to have more success (Bookbinder *et al*. 1998). Care should be taken to ensure that local communities capture ecotourism's benefits, to prevent unrealistically raising local people's expectations of ecotourism's economic potential, and to minimize negative impacts and disturbance by tourists on Livingstone's flying fox and its habitat. Some concerns of this type have already been noted at Ouallah-Miréreni (S. Wells, pers. obs.), and such problems have negatively impacted otherwise successful ecotourism projects in Madagascar and East Africa (e.g., Obua 1997, Ogutu 2002, J. Talbot pers. comm.). These problems could be minimized through community-level revenue-sharing agreements, local accreditation of ecotourist guides, frank discussions of ecotourism's potential and limitations, rules restricting tourist and guide behavior near roost sites, use of observation blinds, and prevention of tourist approaches to roost trees.

Sustainable development through agricultural and forestry extension

Agricultural and forestry extension could also benefit rural Comorians. Farmers throughout the island of Anjouan complain of decreased soil fertility in their fields (E. Granek, B. Sewall, M. Moutui, & I. Saïd, pers. obs.). This loss of soil fertility results partly from cultivation of steep slopes

(in some cases, slopes of greater than 50°) without the use of terracing or other erosion control techniques (CARE-USA, pers. comm., A. Feistner, pers. obs., B. Sewall, unpublished data), and few appear to use crop rotations and crop associations with leguminous plants (B. Sewall and E. Granek, pers. obs.). Rural women also complain about the increasing distance that must be traveled to obtain firewood and water as nearby forests become depleted and rivers run dry (E. Granek, B. Sewall, M. Moutui, & I. Saïd, pers. obs.). Agricultural and forestry extension efforts may address these and other issues, and can provide a viable alternative to economic activities that threaten the survival of Livingstone's flying fox. Such efforts may also result in more sustainable and productive use of land by local people, which in turn can reduce pressure on remaining Livingstone's flying fox habitat.

Past efforts were undertaken by the U.S Peace Corps, and CARE-USA, to encourage utilization of terracing techniques for erosion control and to plant trees in riparian zones to prevent drying of rivers. In addition, CARE-USA oversaw the functioning of a tree nursery on Anjouan, providing fuelwood trees to farmers. The U.S. Peace Corps worked with local Ulanga groups to educate farmers and community members on conservation techniques and ecological processes. These programs ended in 1994 and 1995, respectively, due to loss of funding and political instability.

New agriculture extension efforts might usefully focus on longer-term projects addressing erosion control through contour lines and vegetation breaks, soil fertility improvements through crop rotations and associations, and the use of agroforestry techniques. Forestry extension efforts might focus on training local farmers in tree planting techniques, tree nurseries, sustainable small-scale plantations and wood harvest, associations between trees and crops, and production of fuel-efficient mud cook stoves.

Health Care

Poor health care compromises the ability of rural people to increase their income, send children to school, feed their families, and plan their families. This is not only a serious development and quality-of-life issue; it is also one that impacts the success of conservation programs. Low probability of surviving long into the future can reduce incentives to maintain natural resources, especially those that regenerate slowly (Norgaard & Howarth 1991). Healthy people are more able to prepare for the future and benefit from long-term management efforts, and thus are more interested in sustainable land and natural resource use.

In the Comoros, access to modern health care is limited. Total per capita public and private spending on health care in 2000 was $13 (USD) (World Health Organization 2002). One quarter of children under five years old are underweight (Birdsall & Fukuda-Parr 2002). The expectation of lost healthy years over a lifetime from poor health is 12.8 for men and 11.0 for women (World Health Organization 2002). Life expectancy at birth is 60 years (Birdsall & Fukuda-Parr 2002).

Access to family planning information and services in the Comoros is also limited. In the Union of the Comoros, contraceptive prevalence – the proportion of married women currently using any form of modern contraception – is 11 % (United Nations Population Fund 2002). Unmet need for family planning – the proportion of women who say they desire to space births for at least 2 years or do not want any more children, who are not currently using a family planning method – is 19.5 % for all Comorian women, 35.6 % for rural women, and 51.2 % for women 15-19 years of age (Population Reference Bureau 2002). Infant mortality is 67 per 1000 live births (United Nations Population Fund 2002), and only 62 % of women give birth with skilled attendants (doctors or midwives) (United Nations Population Fund 2002). These issues are certainly even more pronounced in the rural areas near Livingstone's flying fox habitat.

Efforts were undertaken in the past by the United Nations Family Planning Agency, which conducted a program to educate Comorian families about family planning options and correct utilization. U.S. Peace Corps Volunteers focused on combining environmental and health education, teaching rural populations about the environmental effects of large populations and introducing alternatives, including access to family planning strategies. A group of Health and Environment Peace Corps Volunteers on Anjouan worked together to focus activities in rural villages on community education and family planning techniques, working with local Health Care facilities to provide rural access to family planning information and services. However, this project was not sustained after Peace Corps left the islands (E. Granek, pers. obs.). Future combined efforts to both

improve rural Comorians' access to quality healthcare and teach about the interactions between human health and the environment have strong potential to benefit rural populations while also improving the conservation of Livingstone's flying fox and its rainforest habitat.

Education

School enrollment is limited in the Comoros. Among children of primary school age, 82% of boys and 70 % of girls are enrolled in primary schools in the Comoros, but only 27 % of boys and 22 % of girls of secondary school age are enrolled (United Nations Population Fund 2002). Overall, illiteracy is 44.1 % in the Comoros (Birdsall & Fukuda-Parr 2002), and this rate is higher in rural areas. This means that many Comorians are unprepared for formal salaried employment.

Improvements in education are correlated with improved health, a lower population growth rate, and increased economic opportunities. Education is also an important component of developing a more involved citizenship, which in turn, is essential to the success of community-based conservation efforts. Providing a basic understanding of natural processes and ecological interactions is essential to enabling people greater opportunities to participate in management and conservation of their natural resources. Improving education over the long term can develop a generation of individuals who understand the need for and are able to manage natural resources. In this way, education can benefit rural Comorians and conservation of Livingstone's flying fox and the Comorian rainforest.

Broad Aim G: Address important but indirect threats to Livingstone's flying fox, and maximize benefit to all Comorian native biodiversity and the Comorian people by coordinating with other conservation activities and organizations

Conservation Partnerships Program objectives and actions

G.1. Promote sustainable development on Moheli and Anjouan to benefit people living near Livingstone's flying fox habitat and to benefit the conservation of Livingstone's flying fox.
- G.1.a. Cultivation of a common understanding of the objectives of sustainable development and a harmonization of methods between governmental agencies and non-governmental organizations.
- G.1.b. Identification, through dialogue with local residents and potential partner organizations, of objectives for future interventions in sustainable agriculture, sustainable forestry, health, and education to benefit both local residents and Livingstone's flying fox conservation.
- G.1.c. Development of economic alternatives for local people who exploit native forested areas, including distillers, loggers, hunters, and farmers.
- G.1.d. Capacity-building at the local level, using a multidisciplinary approach to Livingstone's flying fox conservation, environmental protection, and the initiation of sustainable development.
- G.1.e. Identification of potential partner organizations and initiation of collaborations in the fields of sustainable agriculture, sustainable forestry, health, and education.

G.2. Promote small-scale ecotourism on Moheli and Anjouan to benefit people living near Livingstone's flying fox habitat and to benefit the conservation of Livingstone's flying fox.
- G.2.a. Identification of potential partner organizations and initiation of collaborations in small-scale ecotourism development.
- G.2.b. Development of village agreements for the sharing of the benefits of ecotourism.
- G.2.c. Training of guides at each ecotourism site on natural history of Livingstone's flying fox, the ecology of the Comoros, cross-cultural education, first aid, and other skills.
- G.2.d. Assistance to local communities to develop revenue-generating activities associated with ecotourism, such as lodging (e.g., bungalows) and sale of food and artisanal goods.
- G.2.e. Development of rules governing guide and tourist behavior near roost sites.

G.3. Improve this Conservation Partnerships Program and plan future actions.

G.3.a. Evaluation of the contribution of this Conservation Partnerships Program to the conservation of Livingstone's flying fox and its rainforest habitat, and to Comorian biodiversity and the Comorian people.

G.3.b. Development of a long-term plan to promote conservation-related revenue-generating activities in the Comoros.

References Cited

Action Comores 1992. *The final report of the University of Bristol Comoros '92 Expedition*. W.J. Trewhella & P.F. Reason. Unpublished report. University of Bristol.

Action Comores 1993. *The final report of the Action Comores 1993 Expedition to the Comoro Islands*. W.J. Trewhella & P.F. Reason. Unpublished report. University of Bristol.

Action Comores 1994. *The final report of the Action Comores 1994 Expedition to the Comoro Islands*. P.F. Reason & W.J. Trewhella. Unpublished report. University of Bristol.

Action Comores 1997. *Action Comores Report 1995-1997 including the 1995 Expedition to the Comoros*. K. M. Clark, S. R. T. Garrett, & P. F. Reason. Unpublished report.

Action Comores 1999. *Report on the Action Comores Livingstone's Flying Fox Monitoring Programme 1992 - 1998*. P.F. Reason, J. Davies, S. Garrett, M. Moutui, I. Saïd, and W. Trewhella. Unpublished report.

Action Comores 2004. Extract of a Report on the Action Comores Livingstone's Flying Fox Monitoring Programme 1992-2003. P.F. Reason, Action Comores International, Action Comores Anjouan. Unpublished report.

Action Comores 2006. Extrait du Rapport sur le Programme de Surveillance de la Roussette de Livingstone Mené par Action Comores de 1992 à 2004. Unpublished report.

Agrar und Hydrotechnik GMBH 1987. *Carte d'occupation des terres aux Comores*. Agrar un Hydrotechnik, Essen.

Ben Mohadji, F. and B. Paris 2000. *Plan d'Action pour la Conservation des Tortues Marines en République Fédérale Islamique des Comores*. Direction Générale de l'Environnement, Projet Biodiversité (PNUD & FEM / IUCN).

Benson, C.W. 1960. Birds of the Comoros Islands. *Ibis* 103b: 1-106.

Birdsall, N., and S. Fukuda-Parr (eds.) 2002. *Human Development Report 2002: Deepening Democracy in a Fragmented World*. United Nations Human Development Report Office, New York.

Boinali, S.A. 2001. Arrêté No. 01/31/MPE/CAB. *Ministère de la Production et de l'Environnement*. Moroni, *République Fédérale Islamique des Comores* [in French].

Bookbinder, M.P., E. Dinerstein, A. Rijal, H. Cauley, and A. Rajouria 1998. Ecotourism's support of biodiversity conservation. *Conservation Biology* 12: 1399-1404.

Brooks, T.M., R.A. Mittermeier, C.G. Mittermeier, G.A.B. da Fonseca, A.B. Rylands, W.R. Konstant, P. Flick, J. Pilgrim, S. Oldfield, G. Magin, and C. Hilton-Taylor 2002. Habitat loss and extinction in the hotspots of biodiversity. *Conservation Biology* 16: 909-923.

Caldecott, J., M. Jenkins, T. Johnson, and B. Groombridge 1996. Priorities for conserving global species richness and endemism. *Biodiversity & Conservation* 5: 699-727.

Carroll, J.B. 1988. The conservation programme for the Rodrigues fruit bat *Pteropus rodricensis*. Pages 457–476 in Dresser, B.L. and E.J. Maruska (eds) *Proceedings of the 5th World Conference on Breeding Endangered Species in Captivity*, eds,. Cincinnati Zoo, Cincinnati.

Carroll J.B. and I. Thorpe 1991. The conservation of Livingstone's fruit bat *Pteropus livingstonii* Gray 1866: A report on an expedition to the Comores in 1990. *Dodo, Journal of the Jersey Wildlife Preservation Trusts* 27: 26-40.

Cheke, A.S. and Dahl, J.F. 1981. The status of bats on western Indian Ocean islands, with special reference to *Pteropus*. *Mammalia* 1, 205-238.

Clark, K.M. 1997. Livingstone's flying fox, I presume ? : Conservation efforts on the Comoros Islands have spurred public action to protect a once-obscure fruit bat *BATS* 15 (1) : 8-13.

Clark, K.M., J.B. Carroll, M. Clark, S.R.T. Garrett, S. Pinkus, and R. Saw 1997. Capture and survey of Livingstone's fruit bats *Pteropus livingstonii* in the Comoros Islands: The 1995 expedition. *Dodo, Journal of the Jersey Wildlife Preservation Trusts* 33: 20-35.

Courts, S.E. 1996a. An ethogram of captive Livingstone's fruit bats *Pteropus livingstonii* in a new enclosure at Jersey Wildlife Preservation Trust. *Dodo, Journal of the Wildlife Preservation Trusts* 32: 15-37.

Courts, S.E. 1996b. *General Behaviour and Social Interactions in a Group of Livingstone's Fruit Bats* Pteropus livingstonii *at Jersey Wildlife Preservation Trust*. Unpublished report, Jersey Wildlife Preservation Trust, Jersey.

Courts, S. E. 1997. Insectivory in captive Livingstone's and Rodrigues fruit bats *Pteropus livingstoni*i an*d P. rodricensi*s (Chiroptera:Pteropodidae): A behavioural adaptation for obtaining protein. *Journal of the Zoological Society of London* 242: 404-410.

Courts, S.E. 1998. Investigation of infant development and juvenile social interactions in Livingstone's fruit bat *Pteropus livingstonii* at Jersey Wildlife Preservation Trust. *Dodo, Journal of the Wildlife Preservation Trusts* 34: 166-167.

Courts, S.E. 1999. Dietary studies of Livingstone's fruit bat *Pteropus livingstonii* at Jersey Wildlife preservation Trust: Feeding behaviour, diet evaluation and modification. *Dodo, Journal of the Wildlife Preservation Trusts* 35: 26-47.

Courts S.E. and A.T.C. Feistner 2000. Nutrition of Old World fruit bats in captivity: Diet studies of Livingstone's fruit bats *Pteropus livingstonii*. Pages 81-90 in: Zoo, Nijboer, J., J.M. Hatt, W. Kaumanns, A.C. Beynen, and U. Ganslosser (eds.). *Animal Nutrition No.1*. Flanders Press.

Doumbe-Bille, S. 2001. Révision de l'avant-projet de loi forestière. *Projet Conservation de la Biodiversité et Développement Durable aux Comores*. Moroni, *République Fédérale Islamique des Comores* [in French].

Foose, T. J., L. de Boer, U.S. Seal, and R. Lande 1995. Conservation management strategies based on viable populations. Pages 273-294 in: Population Management for Survival and Recovery. Pages 273-294 in Ballou, J. D., M. Gilpin, and T.K. Foose (eds) *Analytical Methods and Strategies in Small Population Conservation*, Columbia University Press: New York.

Fowler, M.E. 1993. *Zoo and Wild Animal Medicine: Current Therapy (vol 3)*. W. B. Saunders, Philadelphia.

Fujita, M.S. and M.D. Tuttle 1991. Flying foxes (Chiroptera: Pteropodidae): threatened animals of key ecological and economic importance. *Conservation Biology* 5: 455-463.

Granek, E. 2000. Conservation des habitats des Roussettes de Livingstone – Les massifs forestiers d'Anjouan et Mohéli, Comores : Utilisation d'indicateurs sociaux et écologiques. *Ya Mkobe* 5-6 : 131-137 [In French].

Granek, E. 2002. Conservation of *Pteropus livingstonii* based on roost site habitat characteristics on Anjouan and Mohéli, Comoros Islands. *Biological Conservation* 108: 93-100.

Hawes, J. 2002. *A Comparison of the Roosting Ecology and Diurnality of two Fruit Bats from the Comoros in Relation to the Risk of Hyperthermia, and with Consideration for the Conservation of Livingstone's Flying Fox,* Pteropus livingstonii. Undergraduate thesis, University of Nottingham.

Herron, S. 1993. A preliminary ethogram of captive Livingstone's fruit bats *Pteropus livingstonii* at the Jersey Wildlife Preservation Trust. *Dodo, Journal of the Wildlife Preservation Trusts* 29: 34-44.

Hilton-Taylor, C. (Compiler) 2000. *2000 IUCN Red List of Threatened Species*. IUCN/SSC, Gland, Switzerland and Cambridge, UK. 61 pp.

Hunter K., M. Saïd and E. Walters 1992. Etude sur les utilisations de la forêt naturelle Anjouan, République Fédérale Islamique des Comores. Unpub. report for CARE-Comores, March 1992.

Institut Géographique National 1995a. *Archipel des Comores : Anjouan carte routière au 1 : 50000*. Map. Institut Géographique National, Paris.

Institut Géographique National 1995a. *Archipel des Comores : Mohéli carte routière au 1 : 50000*. Map. Institut Géographique National, Paris.

IUCN 1994. *Species Action Plan for Livingstone's Fruit Bat Pteropus livingstonii*. IUCN Species Survival Commission Chiroptera Specialist Group. Jersey, British Isles, UK. 4pp.

IUCN 2004. Red List of Threatened Species. www.redlist.org

IUDZG/CBSG (IUCN/SSC) 1993. *The World Zoo Conservation Strategy; The Role of Zoos and Aquaria of the World in Global Conservation.* Chicago Zoological Society, Brookfield.

Jacobson, S.K. 1987. Conservation education programmes: evaluate and improve them. *Environmental Conservation* 14: 201-206.

Jacobson, S.K. 1991. Evaluation model for developing, implementing, and assessing conservation education programs: examples from Belize and Costa Rica. *Environmental Management* 15: 143-150.

Jacobson, S.K. and M.D. McDuff 1998. Conservation Education. Pages 237-255 in Sutherland, W.J. (ed), *Conservation Science and Action*. Blackwell Science Limited, Oxford.

Jolly, R. and S. Fukuda-Parr 2000. *Human Development Report 2000.* United Nations Development Programme. Oxford University Press, New York.

Kapos, V. 1989. Effects of isolation on the water status of forest patches in the Brazilian Amazon. *Journal of Tropical Ecology* 5: 173-185.

Kleiman, D. G. 1996. Reintroduction programs. Pages 297-305 in D. G. Kleiman, M. E. Allen, K. V. Thompson, and S. Lumpkin, editors. *Wild Mammals in Captivity*. University of Chicago Press, Chicago.

Kleiman, D.G., R.P. Reading, B.J. Miller, T.W. Clark, J.M. Scott, J. Robinson, R.L. Wallace, R.J. Cabin and F. Felleman 2000. Improving the evaluation of conservation programs. *Conservation Biology* 14: 356-365.

Laurance, W.F., P. Delamonica, S.G. Laurance, H.L. Vasconcelos, and T.E. Lovejoy 2000. Rainforest fragmentation kills big trees. *Nature* 4004: 836.

Laurance, W.F., L.V. Ferreira, J.M. Rankin-de Merona 1998. Rain forest fragmentation and the dynamics of Amazonian tree communities. *Ecology* 79: 2032-2040.

Laurance, W.F., T.E. Lovejoy, H.L. Vasconcelos, E.M. Bruna, R.K. Didham, P.C. Stouffer, C. Gascon, R.O. Bierregaard, S.G. Laurance, and E. Sampaio 2002. Ecosystem decay of Amazonian forest fragments: A 22-year investigation. *Conservation Biology* 16: 605-618.

Lewis, S. 1998. *Treefall gaps and regeneration : A comparison of continuous forest and fragmented forest in central Amazonia*. PhD thesis. University of Cambridge: Cambridge, United Kindgom.

Louette, M. (ed.) 1999. La faune terrestre de Mayotte. *Annales des Sciences Zoologiques du Musée Royale de l'Afrique Centrale,* 284: 1-248 [in French].

Lovejoy, T.E, R.O. Bierregaard Jr., A.B. Rylands, F.R. Malcolm, C.E. Quintela, L.H. Harper, K.S. Brown Jr., A.H. Powell, G.V.N. Powell, H.O. Schubart, and M.B. Hays 1986. Edge and other effects of isolation on Amazon forest fragments. Pages 257-285 in M.E. Soulé (ed.) *Conservation Biology: The Science of Scarcity and Diversity*. Sinauer: Sunderland, Massachusetts.

Mace, G M and J.B. Carroll 1995. Rodrigues fruit bats - population management outline. In J.B. Carroll, L. Gilmour and S. Courts (eds.) *Rodrigues Fruit Bat Pteropus rodricensis International Studbook Volume 1.* Jersey Wildlife Preservation Trust, Jersey.

MacKinnon, J. L., C. E. Hawkins, E. Long, D. Andriafidison, P. A. Racey, R. Andrianaivoarivelo, S. Fidiarisoavoninarino, C. Nirina, M. Raheririarisena, S. Rakamiarison, J. G. Rakotondratsimba, R. Ralisoamala, J. Ranivo, F. Ratrimomanarivo, N. Razadindrakoto, and V. Razakarivony 2000. The conservation of Megachiroptera in Madagascar. Oral presentation to the 30th annual North American Symposium on Bat Research, Miami, Florida.

Masefield, W. 1999. Forage preferences and enrichment in a group of captive Livingstone's fruit bats *Pteropus livingstonii*. *Dodo, Journal of the Wildlife Preservation Trusts* 35: 48-56.

Masefield, W. 2003. European Studbook for Livingstone's Fruit Bat (*Pteropus livingstonii*). European Association of Zoos and Aquaria.

Masefield, W. 2004. Second European Studbook for Livingstone's Fruit Bat (*Pteropus livingstonii*). European Association of Zoos and Aquaria.

Masefield, W. 2005. Third European Studbook for Livingstone's Fruit Bat (*Pteropus livingstonii*). European Association of Zoos and Aquaria.

Mickleburgh, S.P., A.M. Hutson, and P.A. Racey (eds.) 1992. *Old World Fruit Bats: An Action Plan for their Conservation*. IUCN Species Survival Commision Chiroptera Specialist Group. Information Press: Oxford, UK. 252 pp.

Mickleburgh, S.P., A.M. Hutson, and P. Racey 2002. A review of the global conservation status of bats. *Oryx* 36: 18-34.

Mittermeier, R.A., N. Myers, J.B. Thomsen, G.A.B. da Fonseca, and S. Olivieri 1998. Biodiversity hotspots and major tropical wilderness areas: Approaches to setting conservation priorities. *Conservation Biology* 12: 516-520.

Moulaert, N. 1998. *Etude et conservation de la forêt de Mohéli (RFI des Comores), massif menacé par la pression anthropique*. Doctoral thesis. Faculté Universitaire des Sciences Agronomiques, Gembloux [in French].

Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B. da Fonseca, and J. Kent 2000. Biodiversity hotspots for conservation priorities. *Nature* 403: 853-858.

Nicoll, M.E. and P.A. Racey 1981. The Seychelles fruit bat, Pteropus seychellensis seychellensis. *African Journal of Ecology* 19: 361-364.

Nichols, J. D., and M. J. Conroy 1996. Techniques for estimating abundance and species richness. Pages 177-234 in D. Wilson, E., F. R. Cole, J. D. Nichols, R. Rudran, and M. S. Foster (eds.) *Measuring and Monitoring Biological Diversity: Standard Methods for Mammals*. Smithsonian Institution Press, Washington, D. C.

Norgaard, R.B, and R.B. Howarth 1991. Sustainability and discounting the future. In R. Costanza (ed.) *Ecological Economics: The Science and Management of Sustainability*. Columbia University Press: New York.

Nowak, R.M. 1997. Flying foxes. *Walker's Mammals of the World 5.1*. Johns Hopkins University Press. [online]: http://www.press.jhu.edu/books/walker/chiroptera/chiroptera.html.

Obua J. 1997. The potential, development and ecological impact of ecotourism in Kibale National Park, Uganda. *Journal of Environmental Management* 50: 27-38.

Ogutu Z.A. 2002. The impact of ecotourism on livelihood and natural resource management in Eselenkei, Amboseli Ecosystem, Kenya. *Land Degradation & Development* 13: 251-256.

Padua, S.M. 1994. Conservation awareness through an environmental education programme in the Atlantic forest of Brazil. *Environmental Conservation* 21: 145-151.

Paynter, E. 2001. *Nutritional Analysis of the Livingstone's Fruit Bat* Pteropus livingstonii *Diet at Jersey Zoo*. BSc. thesis, University of East London.

Pierson, E.D. and W.E. Rainey 1992. The biology of flying foxes of the genus *Pteropus*: A review. Pages 1-17 in Wilson, D.E. and G.L. Graham (eds.). *Pacific Island Flying Foxes: Proceedings of an International Conservation Conference*. U.S. Fish and Wildlife Service, Washington, D.C. Biological Report 90(23).

Population Reference Bureau 2002. Comoros: Demographic Highlights. [Online] http://www.prb.org/pdf/Comoros_Eng.pdf

Princeé, F. P. G. 1995. Overcoming the constraints of social structure and incomplete pedigree data through low-intensity genetic management. Pages 124-154 in J. D. Ballou, M. Gilpin, and T. J. Foose, editors. *Population Management for Survival and Recovery: Analytical Methods and Strategies in Small Population Conservation*. Columbia University Press, New York.

Ramsay, S., D. Houston, W. Masefield, D. Wormell in preparation. An investigation into the effects of increased exercise on muscle volume in captive Livingstone's fruit bats at Durrell Wildlife Conservation Trust.

Reason, P.F., W.J. Trewhella, J.G. Davies, and S. Wray 1994. Some observations on the Comoro rousette *Rousettus obliviosus* on Anjouan (Comoro Islands: Western Indian Ocean). *Mammalia* 58: 397-403.

Robertson, P.B. 1992. Small islands, natural catastrophes, and rapidly disappearing forests : A high vulnerability recipe for island populations of flying foxes. Pages 41-45 in Wilson, D.E. and G.L. Graham. *Pacific Island Flying Foxes: Proceedings of an International Conservation Conference*. Biological Report 90:23. U.S. Fish and Wildlife Service, Washington, D.C.

Roby, D. and M.B. Dossar 2000. *Stratégie Nationale et Plan d'Action pour la Conservation de la Diversité Biologique*. Ministère de la Production et de l'Environnement and Projet PNUD/FEM/COI/97/GEF31. Moroni, République Fédérale Islamique des Comores [In French].

Rogers, G.B. 1998. *Competition as a Factor in the Endangered Status of Livingstone's Fruit Bat*. Undergraduate thesis. Princeton University.

Rodríguez-Clark, K. M. 2002. *The conservation of quantitative genetic variation in small populations: Experiments with* Oncopeltus fasciatus *(the large milkweed bug)*. Ph. D. Thesis, Department of Ecology and Evolutionary Biology, Princeton University, 226 p.

Santos, A.M., and M. Tabarelli 2002. Distance from roads and cities as a predictor of habitat loss and fragmentation in the caatinga vegetation of Brazil. *Brazilian Journal of Biology* 62 (4B): 897-905.

Sewall, B.J. 2002. *Fruit Bat Ecology and Conservation in the Comoros Islands*. Masters thesis. University of Minnesota, St. Paul, Minnesota.

Sewall, B.J. 2003a. Fruit bats on the brink. *Zoo Matters: The Magazine for Supporters of Bristol Zoo Gardens*. Winter 2003: 9-10.

Sewall, B.J. 2003b. Giant bats face a shrinking forest. *BATS.* 21(4) 8-11.

Sewall, B.J. and E.F. Granek 2000. Les roussettes des Comores. Annex in Roby, D. and M.B. Dossar *Stratégie Nationale et Plan d'Action pour la Conservation de la Diversité Biologique*. Ministère de la Production et de l'Environnement and Projet PNUD/FEM/COI/97/GEF31. Moroni, République Fédérale Islamique des Comores.

Sewall, B.J., E.F. Granek et W.J. Trewhella 2003. The endemic Comoros Island fruit bat *Rousettus obliviosus*: ecology, conservation, and Red List status. *Oryx* 37(3): 344-352.

Terborgh, J. and B. Winter 1980. Some causes of extinction. Pages 119-134 in M.E. Soulé and B.A. Wilcox (eds.). *Conservation Biology: An Evolutionary-Ecological Perspective.* Sinauer Associates, Sunderland, Massachusetts.

Trewhella, W.J., P.F. Reason, J.G. Davies, and S. Wray 1995. Observations on the timing of reproduction in the congeneric Comoro Island fruit bats*, Pteropus livingstonii* (Gray 1866) and *P. seychellensis comorensis* (Nicoll 1908*). Journal of Zoology, London* 70, 327-331.

Trewhella, W.J., P.F. Reason, R.J. Bullock, J.B. Carroll, C.C.M. Clark, J.G. Davies, R. Saw, S. Wray, and J. Young 1995. Conservation of *Pteropus livingstonii:* Catching fruit bats in the Comores. *Myotis* 32-33: 297-305.

Trewhella, W.J., P.F. Reason, K.M. Clark, and S.R.T. Garrett 1998. The current status of Livingstone's flying fox (*Pteropus livingstonii*) in the Federal Islamic Republic (RFI) of the Comores. *Phelsuma* 6: 32-40.

Trewhella W.J., K.M. Rodríguez-Clark, N. Corp, A. Entwistle, S.R.T. Garrett, E.F. Granek, K.L. Lengel, M.J. Raboude, P.F. Reason, and B.J. Sewall 2005. Environmental education as a component of multi-disciplinary conservation programs: Lessons from conservation initiatives for critically endangered fruit bats in the western Indian Ocean. *Conservation Biology* 19:75-85.

Trewhella, W.J., K.M. Rodríguez-Clark, J.G. Davies, P.F. Reason, and S. Wray 2001. Sympatric fruit bat species (Chiroptera: Pteropodidae) in the Comoros Islands (Western Indian Ocean): diurnality, feeding interactions and their conservation implications. *Acta Chiropterologica* 3: 135-147.

United Nations 1973. Convention on International Trade in Endangered Species of Fauna and Flora. United Nations, Washington, D.C.

United Nations 1992. Convention on Biological Diversity. United Nations, Rio de Janiero.

United Nations 2001. Fruit bat conservation in the Comoros archipelago. *Sustainable Development Success Stories: Special Issue on Small Island Developing States*. United Nations Division for Sustainable Development: New York.

United Nations Development Programme 1998. *Conservation of Biodiversity and Sustainable Development in the Federal Islamic Republic of the Comoros*. Unpublished report.

United Nations Population Fund 2002. *State of the World Population 2002: People, Poverty, and Possibilities.* United Nations Population Fund: New York.

Waters, D., I. Thorpe, P.A. Turner, and L. Gilby 1988. *University of East Anglia Comoro Islands Expedition 1988.* Unpublished report, University of East Anglia.

Weightman B. 1987. *The Crisis on Anjouan.* Unpublished report to the Food and Agriculture Organization, Rome.

World Bank Group 2002. *World Development Indicators Database 2002*. [Online]: http://www.worldbank.org/data/dataquery.html

World Health Organization 2002. Selected Indicators: Comoros. [Online]: http://www3.who.int/whosis/country/indicators.cfm?country=com

World Resources Institute 1993. *World Report 1991-1992: A Guide to the Global Environment*. Oxford University Press, New York.

Young, J.A., R. Saw, W.J. Trewhella, and C. Cole 1993. Establishing a captive breeding programme for the endangered Livingstone's fruit bat *Pteropus livingstonii*: the 1993 capture expedition. *Dodo, Journal of the Wildlife Preservation Trusts* 29**:** 22-33.

Annex 1 : Conservation Strategy for other Comorian Fruit Bats

Fruit bats of the Comoros Islands [4]

Bats are comprised of two main groups : megachiropterans and microchiropterans. Megachiropterans, or Old World fruit bats, are the large plant-visiting bats that feed on fruit, flowers, and occasionally leaves of trees and other plants. In addition to Livingstone's flying fox (*Pteropus livingstonii*), there are two other Comorian fruit bat species: the Comoros rousette (*Rousettus obliviosus*) and the Comoros yellow-headed (or common) flying fox (*Pteropus seychellensis comorensis*). The Comoros rousette is endemic to three islands, Grande Comore, Moheli, and Anjouan (Louette 1999, Sewall *et al*. 2003). It is nocturnal, and rarely seen by local people. The Comoros yellow-headed flying fox appears to be relatively common, and is found on all four of the Comoros Islands as well as the island of Mafia in Tanzania. Another subspecies of *Pteropus seychellensis* exists in the Seychelles. The Comoros yellow-headed flying fox is very familiar to local people, as it is frequently observed within villages and cities roosting during the daytime and foraging during the late afternoon and evening.

The abundance of the Comoros rousette is estimated as at least 7,000 individuals (Sewall *et al.* 2003). The abundance of the Comoros yellow-headed flying fox is not known, but is much higher than that of Livingstone's flying fox. While foraging, each of these bat species disperse seeds and pollinate flowers of native tree species. This process is likely to be important for the maintenance of native forest, and for regeneration of the forest in cleared areas (Fujita & Tuttle 1991). Both of these species have legally protected status, the Comoros rousette as an 'integrally protected species' (list 1 in Boinali 2001; see page 14 of this *Conservation Action Plan* for more details of list 1 prohibitions) and the Comoros yellow-headed flying fox as a 'partially protected species' (list 2 in Boinali 2001; contains similar prohibitions to list 1, but certain actions are allowed with a previously-obtained permit). In addition, the Comoros yellow-headed flying fox receives protection under CITES as an Appendix II species (United Nations 1973; see pages 14-15 of this *Conservation Action Plan* for more details of CITES protections). The Comoros rousette is considered Near Threatened by IUCN (2004), though was considered Vulnerable by Sewall and colleagues (2003). The Comoros yellow-headed flying fox is considered Least Concern by IUCN (2004).

Conservation of Comorian fruit bats

As one step in keeping with the mission of this *Conservation Action Plan* to protect other Comorian biodiversity, a brief mention of means to conserve Comoros rousette and the Comoros yellow-headed flying fox is included here. Many of the activities outlined in the Conservation Strategy of the *Conservation Action Plan for Livingstone's Flying Fox* will also likely benefit the Comoros rousette and the Comoros yellow-headed flying fox. It is important that the conservation needs of both of these species be addressed during the implementation of this *Conservation Action Plan*, and during the Livingstone's flying fox environmental education program in particular. In addition,, based on research on these species (Mickleburgh *et al.* 1992, Sewall 2002, Sewall *et al.* 2003, Reason *et al*. 1994, Nicoll & Racey 1981), the following additional steps are strongly recommended.

Conservation of the Comoros rousette (*Rousettus obliviosus*)

- Ro.1. Protect Comoros rousette roost caves, especially the caves with the largest known colony on each island, Panga Chilamouinani near Fassi on Grande Comore, Bakomdrundru near Ndrondroni on Moheli, and a shallow cave near Limbi on Anjouan.
- Ro.2. Discourage hunting of all fruit bats through environmental education.
- Ro.3. Conduct a comprehensive field search for more Comoros rousette roost sites.
- Ro.4. Provide incentives to landowners owning land near roost caves to conserve caves and bats.
- Ro.5. Devise a suitable population monitoring protocol for the Comoros rousette and conduct twice-yearly visits to all Comoros rousette roost sites to obtain population estimates.

[4] Adapted from Sewall & Granek (2000)

Conservation of the Comoros yellow-headed flying fox (*Pteropus seychellensis comorensis*)

Psc.1. Discourage hunting of all fruit bats through environmental education.

Psc.2. Encourage the Société Comorienne d'Electricité et d'Eau (CEE) to insulate electric wires or widen gaps between electric wires, so as to minimize fruit bat deaths from electric shock.

Psc.3. Conduct a survey of Comoros yellow-headed flying fox roost sites to establish the approximate number of colonies and colony sizes existing on each of the three islands.

Psc.4. Monitor twice-yearly Comoros yellow-headed flying fox roost sites with colonies of greater than 100 individuals.

Annex 2: Author contact information

Brent J. Sewall, Department of Wildlife, Fish, and Conservation Biology, University of California – Davis, One Shields Avenue, Davis, CA 95616 USA; tel. 1 (530) 752-3203 or 1 (410) 268-2529; fax: 1 (530) 752-4154; email: bjsewall@ucdavis.edu, brent_sewall@hotmail.com

Elise F. Granek, Department of Zoology, 3029 Cordley Hall, Oregon State University, Corvallis, OR 97331, USA; tel. 1 (541) 737-5359; email: graneke@science.oregonstate.edu

Mohamed F.E. Moutui, Action Comores antenne Anjouan, B.P. 279, Mutsamudu, Anjouan, Union des Comores, Western Indian Ocean; tel. (269) 71.02.54, (269) 34.18.00; fax: (269) 71.02.52; email: momou_57@yahoo.fr, action_comores@ifrance.com, action_comores@hotmail.fr, action_comores@yahoo.fr

Will J. Trewhella, Action Comores – International, Cresswell Associates, The Mill, Brimscombe Port, Brimscombe, Stroud, GL5 2QG; tel: 01453 731231; fax: 01453 887979; email: WTrewhella@cresswell-associates.com, wjt@Cs.Nott.AC.UK

Paola F. Reason, Action Comores – International, The Old Rectory, Stansfield, Sudbury, Suffolk CO10 8LT, UK; email: jon-paola@actcom.freeserve.co.uk

Kathryn M. Rodríguez-Clark, Laboratorio de Ecología y Genética de Poblaciones, Centro de Ecología Instituto Venezolano de Investigaciones Científicas, Apartado 21827 Caracas 1020-A, Venezuela; email: kate@sigmaxi.org, kmrc@ivic.ve

Ishaka Saïd, Action Comores antenne Anjouan, B.P. 279, Mutsamudu, Anjouan, Union des Comores, Western Indian Ocean; phone (269) 71.02.54; fax (269) 71.02.52; email: action_comores@ifrance.com, action_comores@hotmail.fr, action_comores@yahoo.fr

J. Bryan Carroll, Bristol Zoo Gardens, Clifton, Bristol, BS8 3HA, UK; tel. 44 (0)117 974 7305 or 44 (0)117 974 7300, email: bcarroll@bristolzoo.org.uk

Will Masefield, Durrell Wildlife Conservation Trust, Les Augres Manor, Trinity, Jersey JE3 5BP, British Isles, UK; email: will.masefield@durrell.org

Nassuri Toilibou, Action Comores antenne Anjouan, B.P. 279, Mutsamudu, Anjouan, Union des Comores, Western Indian Ocean: phone (269) 71.02.54; fax (269) 71.02.52; email: toilibou@voila.fr, action_comores@ifrance.com, action_comores@hotmail.fr, action_comores@yahoo.fr

Michel Vély, Megaptera Océan Indien et Marine Conservation Society, B.P. 1132, Djibouti (Horn of Africa); email : megaptera@intnet.dj, mcsdjibouti@hotmail.com

Faissoili ben Mohadji, Ministère du Développement Rural et de l'Environnement, Fomboni, Mohéli, Union des Comores, Western Indian Ocean, (269) 72-09-53 or (269) 72-09-12, email: amsoili@yahoo.fr

Anna T.C. Feistner, Centre ValBio, Institute for the Conservation of Tropical Environments, B.P. 33, Ranomafana National Park, 312 Ifanadiana, Madagascar, email: anna@feistner.com

Sue Wells, c/o United Nations Environmental Programme World Conservation Monitoring Centre, 219 Huntingdon Road, Cambridge CB3 ODL, United Kingdom, 44 (0) 1223-277-314; email: sue.wells@unep-wcmc.org, suewells100@tiscali.co.uk