

Environmental Education as a Component of Multidisciplinary Conservation Programs: Lessons from Conservation Initiatives for Critically Endangered Fruit Bats in the Western Indian Ocean

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Abstract: *Pteropus livingstonii*, *P. voeltzkowi*, and *P. rodricensis* are three critically endangered fruit bats from western Indian Ocean islands for which multidisciplinary conservation programs have been established that include environmental education programs (EEPs). We describe these EEPs in terms of the strategies used to achieve them and evaluate the educational and conservation outcomes and impacts of the programs. Educational outputs (including posters, stickers, videos, lesson plans, and workshops), primarily linking human needs to the ecosystem services provided by bats, were delivered to schools and community groups, and local environmental educators were trained to further develop the EEPs. Outcomes included increased local awareness about the bats and their conservation, training of environmental educators, inclusion of bat conservation and environmental issues in the school curricula, and establishment of community-based environmental non-governmental organizations (NGOs). Extensive prior planning, presentations in local languages, distribution of outputs through existing networks of educators, training of local educators, establishment of local environmental NGOs, and local capacity-building were all associated with these EEPs achieving their goals in the under-resourced island locations where these bats are found. The EEPs were also important in the development of other components of their respective conservation programs, such as population monitoring programs. Although long-term conservation impacts, particularly tackling habitat loss, are slow to materialize and social and economic issues need to be addressed, these EEPs have already had important outcomes and have established the foundation for future conservation actions.

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Paper submitted October 29, 2002; revised manuscript accepted June 16, 2004.

Key Words: *Pteropus*, western Indian Ocean

Educación Ambiental como un Componente de Programas Multidisciplinarios de Conservación: Lecciones de Iniciativas de Conservación para Murciélagos Frugívoros en Peligro Crítico en el Océano Índico Occidental

Resumen: *Pteropus livingstonii*, *P. voeltzkowi*, y *P. rodricensis* son tres especies de murciélagos frugívoros en peligro crítico en islas del Océano Índico Occidental para las que se han establecido programas multidisciplinarios de conservación que incluyen programas de educación ambiental (PEE). Describimos estos PEE en términos de las estrategias utilizadas para llevarlos a cabo y los evaluamos en relación con sus resultados e impactos educativos y de conservación. Productos educativos (incluyendo carteles, calcomanías, videos, planes de enseñanza y talleres), principalmente relacionando necesidades humanas con los servicios ecológicos proporcionados por murciélagos, fueron entregados a escuelas y grupos comunitarios, y se capacitó a educadores ambientales locales para desarrollar los PEE. Los resultados incluyeron incremento en la percepción local sobre los murciélagos y su conservación, capacitación de educadores ambientales, inclusión de temas de conservación y ambientales en el currículo de escuelas y el establecimiento de organizaciones no gubernamentales (ONG) ambientales basadas en comunidades. El logro de la metas de los PEE en las localidades insulares donde ocurren estos murciélagos estuvo asociada con extensiva planificación previa, presentaciones en idiomas locales, distribución de productos a través de redes de educadores, capacitación de educadores locales, establecimiento de ONG ambientales locales y capacitación local. Los PEE también fueron importantes en el desarrollo de otros componentes de sus respectivos programas de conservación, tal como programas de monitoreo de poblaciones. Aunque los impactos de la conservación a largo plazo, particularmente la pérdida de hábitat, materializan lentamente y se requiere atender asuntos sociales y económicos, estos PEE ya han tenido resultados importantes y han establecido la base para futuras acciones de conservación.

Palabras Clave: Océano Índico Occidental, *Pteropus*

Introduction

Many current conservation issues are symptoms of larger, more complex problems that are beyond the scope of any one discipline (Kessler et al. 1998). Successfully addressing these issues requires a diverse range of skills and activities (e.g., environmental education, ecological research, management, legislation, and enforcement) coupled with effective partnerships between organizations with these skills (Jacobson 1995; Kessler et al. 1998) and regular program evaluation (Ehrenfeld 2000; Kleiman et al. 2000).

As a component of multidisciplinary conservation efforts, environmental education programs (EEPs) have the potential to increase ecological awareness, foster favorable attitudes toward the environment, and promote natural resource conservation (Jacobson 1991). At their best, they may produce significant behavioral changes in their target audience (Jacobson 1987; Padua 1994) and may be more crucial to successful long-term conservation than biologically focused scientific work (Jacobson & McDuff 1998). The early establishment of EEPs can provide a foundation on which longer term conservation plans can be built. Fien et al. (2001) identified various strategies used in EEPs to form a continuum from information provision, to communication, to education, and finally to capacity building. Although these strategies may overlap in their methodologies, each strategy subsumes the previous one and is capable of contributing successively more to ef-

fective conservation. Evaluation of EEPs that incorporate these strategies should be addressed in terms of their outputs (the material products of the programs), outcomes (the immediate achievements or changes brought about by the programs), and impacts (longer term cumulative effects of the programs; Fien et al. 2001).

Fruit bats (Chiroptera: Pteropodidae) face severe threats, such as habitat and roost destruction, hunting, and storm damage, that are exacerbated by their restricted ranges and island distributions in under-resourced tropical nations (Mickleburgh et al. 2002). The World Conservation Union (IUCN) action plan for old world fruit bats (Mickleburgh et al. 1992) recognizes the need for multidisciplinary approaches to their conservation and describes, as "an almost universal need," EEPs that could address some of the threats. General recommendations include programs emphasizing the important role fruit bats play in forest ecosystems (particularly on small oceanic islands where they are keystone pollinators and seed dispersers; Cox et al. 1992), problems with hunting, and threats posed by habitat destruction and roost disturbance (Mickleburgh et al. 1992; Morton & Murphy 1995).

The western Indian Ocean is home to three critically endangered (IUCN 2003) fruit bat species. Livingstone's flying fox (*Pteropus livingstonii*) is endemic to the islands of Moheli and Anjouan in the Union of the Comoros; the Pemba flying fox (*P. voeltzkowi*) is endemic to Pemba Island, Tanzania; and the Rodrigues flying fox

(*P. rodricensis*) is endemic to the island of Rodrigues in the Republic of Mauritius. By 1992 all three species and their habitats were thought to have undergone significant declines, with surveys indicating very small and vulnerable populations (Cheke & Dahl 1981; Mickleburgh et al. 1992). As a result, multidisciplinary conservation programs were initiated and conservation recommendations were formalized in the IUCN action plan.

We describe the strategies used to implement independent EEPs for *P. livingstonii*, *P. voeltzkowi*, and *P. rodricensis*; evaluate their outputs, outcomes, and impacts in the context of their respective conservation programs; and provide recommendations for the design and implementation of EEPs as components of multidisciplinary conservation programs elsewhere.

Establishment of EEPs as Components of Conservation Programs

Conservation recommendations from the IUCN action plan for these three fruit bat species included ecological research, population monitoring and surveys, habitat protection, hunting reduction, captive breeding programs, and EEP establishment (Mickleburgh et al. 1992). Prior to the 1990s, there had been few ecological studies of these three species (Cheke & Dahl 1981; Mickleburgh et al. 1992). Survey work and monitoring was necessary because studies of existing populations that yielded estimates of <200 individuals in all three cases were neither consistent in their methodologies nor comprehensive in the area they covered.

On all three island groups, bats are threatened directly or indirectly by human activities. Wood is widely used for timber and fuel, and land is cleared for subsistence farming, resulting in deforestation at an unsustainable rate and loss of the bats' principal habitat (Entwistle & Corp 1997a; Jones 1998; Trehwella et al. 2001). Many of the islanders are subsistence farmers or fishers living in village communities, although in Rodrigues the standard of living is higher and the population growth rate lower, compared with Pemba and the Union of the Comoros (UNICEF 2001). Roosts of all three species have been destroyed as a result of tree felling (W.J.T., personal observation; Cheke & Dahl 1981; Entwistle & Corp 1997a), and deforestation can exacerbate the vulnerability of bats to storm damage (Craig et al. 1994). There is no evidence of *P. livingstonii* being hunted for food, but both *P. voeltzkowi* and *P. rodricensis* have been hunted for local consumption (Anonymous 1977; Cheke & Dahl 1981). Hunting of *P. rodricensis*, however, is now rare. The use of shotguns has replaced traditional hunting methods for *P. voeltzkowi*, resulting in a higher, potentially unsustainable impact on the population (Entwistle & Corp 1997a).

The goals of the EEPs were set based on the preceding information and with inputs from ecologists, local and

international educators, local nongovernmental organizations (NGOs), and government staff. The three EEPs were developed independently but with collaborative evaluation. Goals and strategies employed by the programs included:

- raising awareness about the existence of and threats to the species locally and internationally (information provision, communication);
- fostering national pride in the existence of locally unique species (information provision, communication);
- developing educational resources highlighting the connection between local human needs and the ecosystem services provided by bats (communication);
- training local educators (capacity building);
- promoting knowledge and understanding of the conservation issues relating to the bats and the anthropogenic threats to the bats and their environment (education);
- promoting local involvement in conservation programs, particularly by getting locals to assist with population surveys, which increased survey accuracy (capacity building); and
- developing and enhancing local conservation policy making (capacity building).

Design and Delivery of EEP Outputs

Union of the Comoros

Between 1992 and 1995, the NGO Action Comores (International) developed an EEP with a range of outputs and strategies (Table 1). The program used *P. livingstonii* as a flagship species to promote the protection of native forest and its associated fauna, stressing the interdependence of bats, forests, and people and incorporating surveying and monitoring of bats. The EEP has continued because of the work of Projet Conservation de la Biodiversité et Développement Durable aux Comores (an IUCN/Comorian government project funded by the Global Environment Facility and the U.N. Development Programme); Action Comores (antenne Anjouan), whose focus is conservation of *P. livingstonii*; and Ulanga, which has a broader environmental remit. Education outputs were also taken to Mayotte, another island of the Comoros archipelago that shares similar environmental problems but is a politically separate French territorial community.

Because few Comorians knew about Livingstone's flying fox, information provision about its conservation requirements was a key first step. The target audiences were government staff (through the provision of information packs, scientific reports, and conservation recommendations) and villagers living close to roosts (through posters, stickers, a locally shot video, design of a sari-like dress

Table 1. Environmental education goals in the Union of the Comoros, with associated strategies, outputs, outcomes, and impacts.

Goal	Strategy ^a	Output/activity	Outcome (o)/impact (i)
Raise awareness	IP	2400 stickers with bat logo; 450 bat posters; 50 videos; chiromani; radio/TV presentations	increased awareness about bats & conservation issues via NGOs ^b & government officials (o)
	C E, CB IP, E	theatrical presentation developed by Peace Corps ecotourism initiative on Moheli educational role of bats in zoos ^c ; Discovery Channel Canal+ & film <i>Land of the Giant Bats</i>	international awareness about bats (o)
Develop resources	IP	30 bat & forest slide packs/lecture notes; 115 lesson plans on forests; 20 English comprehension exercises	increased awareness about bats & conservation issues via educators & NGOs (o)
	IP, C E, CB	30 field identification sheets for roost monitors training for environmental educators & park guards	trained educators & park guards (o)
Promote knowledge	E	touring workshop to 20 villages near bat roosts (2700 people)	increased awareness about bats & conservation issues via NGOs (o)
Foster pride	C	various outputs	pride in uniqueness of endemic <i>Pteopus livingstonii</i> (o)
Involve locals	E, CB	roost monitor training	roost monitoring program (o)
		survey program by local NGO	improved survey program identified 16 roosts (i)
		ecological training of technician	technician trained to help visiting researchers (o)
	CB	tree planting by Ulanga	4000 trees planted to protect rivers (i)
	CB CB	forest reserve on Moheli setting up of Action Comores (antenne Anjouan)	roost protection (i) establishment of community-based NGO (o)
Form policy	IP, CB	discussions with government & local NGO	protection of individuals in conservation (i) protection of bats & roosts via environmental policies, action plans, & local bylaws ^d (o)

^aStrategy: IP, information provision; C, communication; E, education; CB, capacity building.

^bNongovernmental organizations.

^cCaptive breeding populations of *P. livingstonii* held at Bristol and Jersey zoos in the United Kingdom.

^dNational Environment Policy (1993), Environmental Action Plan (1994), Strategy & National Plan of Action for Biodiversity Conservation (1988).

called a chiromani, theatrical presentations, and touring workshops). Outputs were developed in Chindzouani and French. Because the public education system of the Union of the Comoros functioned sporadically during the 1990s, initial training and educational resources were aimed at educators working for foreign agencies (Peace Corps and CARE-Comores), who provided environmental education training to teachers and direct environmental education in schools and local communities. Park guards on Moheli were also trained by Projet Conservation de la Biodiversité et Développement Durable aux Comores. Villagers living near roosts were trained, equipped, and paid to survey and monitor bats. This program had the additional goal of increasing local awareness and participation in the conservation program and resulted in the establishment of the NGO Action Comores (antenne Anjouan). A technician was also trained to work on the program and support other ecological research.

Pemba

As part of an effort to determine the status of *P. voelzkowi*, an EEP was established in Pemba's schools in 1992 that focused on seed dispersal and forest regeneration, with

outputs including posters, teaching packs, and oral presentations (Seehausen et al. 1994). An additional EEP was conducted in 1995 to build on this project. The 1995 program involved a range of outputs and strategies (Table 2) and added additional components on the endemic nature of *P. voelzkowi*, a population assessment, and ecological studies (Entwistle & Corp 1997a, 1997b). An evaluation of the impact of the 1992 project was carried out, and the results were incorporated into the 1995 program. The EEP has continued through the work of the Sub-Commission for Forestry, now the Department of Commercial Crops, Fruit and Forestry (DCCFF).

The EEP had a school-based focus because most of the larger villages have a primary school and the education system functions well. The 1995 EEP centered on a discussion-led, interactive presentation in Kiswahili given by staff of the Sub-Commission for Forestry to schools, principally in areas close to roosts. Students received a leaflet and sticker and were encouraged to discuss what they had learned with family and friends and to become "ambassadors" for the bats. Presentations were also given to village elders in areas close to bat roosts. Information and lesson plans were provided to the Ministry of Education with the hope that they could be incorporated into

Table 2. Environmental education goals in Pemba, with associated strategies, outputs, outcomes, and impacts.

Goal	Strategy ^a	Output/activity	Outcome (o)/impact (i)
Raise awareness	IP	2000 stickers with bat logo; 2000 leaflets; video	increased awareness about bats & conservation issues via school & community projects (o)
Develop resources	C	420 t-shirts; prizes for environmental clubs	increased awareness about bats & conservation issues (o)
	IP	25 lesson plans given with bat book ^b to DCCFF ^c	
Train educators	E, CB	training for environmental educators & outreach officers in DCCFF (originally 3, now 6)	trained original DCCFF educators who now train new educators (o)
Promote knowledge	E	79 presentations & discussions to schools & village groups near roosts, reaching 5600 students	increased awareness about bats & conservation via school & community-based projects (o)
	C	37 meetings & 3 workshops with community leaders	
Foster pride	C	various outputs	pride in uniqueness of endemic <i>Pteropus voeltzkowi</i> (o)
Involve locals	E, CB	roost monitoring training survey program by environmental clubs & DCCFF	trained monitors (o) improved survey program of 43 roosts (i)
	CB	ecological training of villagers & DCCFF staff setting up of 8 community-based environmental clubs environmental clubs protect bat roosts & habitats	local involvement in research (o) establishment of environmental clubs (o); participation of individuals in conservation (i) larger bat colonies & key habitat protection (i)
Form policy	IP, CB	discussions with 1 environmental club	regulation of bat hunting via bylaws (i)

^aStrategy: IP, information provision; C, communication; E, education; CB, capacity building.

^bThompson & Richardson 1993.

^cDepartment of Commercial Crops, Fruit and Forestry.

the curriculum. The DCCFF has continued the EEP in schools and local communities, employed environmental educators, and distributed a locally produced video on the bat conservation project. A series of workshops and community meetings discussed the threats linked to the continued hunting of *P. voeltzkowi* and the potential opportunities for viewing bats as a long-term, managed resource. In 1997 community-based environmental clubs were established at a number of villages to protect bats and their roosts. Both these clubs and the DCCFF played a role in monitoring local roosts and surveys and now take the lead in such assessments.

Rodrigues

In 1993 the Zoological Society of Philadelphia, in consultation with the local NGO Mauritian Wildlife Foundation, developed an EEP for bats on Rodrigues (Jamieson 1996). In 1997 a local community environmental educator was trained and established on Rodrigues (Jamieson 1998), and after a year evaluation of this post resulted in its continuation. The EEP initially sought to provide information about bats in general and about *P. rodricensis* and its conservation issues in particular. Later it sought to facilitate attitudinal and behavioral changes that would result in a positive impact on Rodrigues' environment (Jamieson 1998). Table 3 details the outputs and strategies used.

Initially, the EEP was designed around a kit developed by the American Zoo and Aquarium Association's (AZA) Bat Taxon Advisory Group's Education Subcommittee.

The kit contained teaching tools that addressed bat conservation concerns worldwide. Because the first kit was developed specifically for testing on Rodrigues, local educators and administrators provided input and advice on the school-age target group (10-year-olds). Kit contents were designed to be fun and interactive, to meet Mauritian curriculum learning objectives (Lewis et al. 1995), and to take advantage of the existing strong school infrastructure on Rodrigues. In 1995 staff from the Philadelphia Zoo demonstrated use of the kit to Rodrigues teachers at a training workshop and used it in introductory lessons. The local community environmental educator later expanded the EEP to address broader anthropogenic threats to the environment by making contact with village leaders and school and community groups; developing additional school curricula; sponsoring an island-wide environmental awareness event; and establishing community-based environmental action projects (Jamieson & Whitman 1998; Whitman 2000). The educator and Mauritian Wildlife Foundation staff also provided support to visiting researchers.

Evaluation of Education and Conservation Outcomes and Impacts

Conservation and education impacts are difficult to measure and evaluate, so evaluation focuses on proxies, such as outcomes (shorter-term achievements or changes

Table 3. Environmental education goals in Rodrigues, with associated strategies, outputs, outcomes, and impacts.

Goal	Strategy ^a	Output/activity	Outcome (o)/impact (i)
Raise awareness	IP	50 bat posters	increased awareness about bats (o)
Develop resources	IP, E	educational role of bats in zoos ^b	international awareness about bats (o)
	IP, C	2 bat education kits containing bat photographs & artwork, bat costume & puppet, board game, information on bat food, video entitled <i>Very Elementary Bats</i> , books, ^c notebook to accompany & interpret education kit, lesson plans with student activities & questionnaires	increased awareness about bats & conservation issues via school & community projects (o)
Train educators	E, CB	workshops for training environmental educators	trained teachers (o)
Promote knowledge	E	training of community environmental educator	establishment of community educator post (o)
		community meetings to promote conservation issues	increased awareness about bats & conservation issues via school & community projects (o)
Foster pride	C	teaching by community environmental educator	conservation issues included in curriculum (o)
		development of school curriculum	pride in uniqueness of endemic <i>Pteropus rodricensis</i> (o)
Involve locals	C, CB	various outputs	surveys identified 4 new roosts (i)
		information on roosts from villagers & MWF ^d staff	local involvement in research (o)
	CB	ecological research support by villagers & MWF staff	establishment of community-based projects (o)
		local community projects set up by MWF	participation of individuals in conservation (i)
CB	MWF develops forest reserves for native trees	2 reserves used by bats as feeding sites (i)	
CB	waste management programs & endemic flora gardens	additional environmental programs (i)	

^aStrategy: IP, information provision; C, communication; E, education; CB, capacity building.

^bCaptive breeding populations of *P. rodricensis* held at 31 zoos internationally.

^cWood & Rink 1991; Greenway 1991; Cannon 1993.

^dMauritian Wildlife Foundation.

brought about by the program) and potential or achieved impacts (longer term cumulative effects of the program; Fien et al. 2001). Because circumstances differ on each island group, the outcomes and impacts of the EEPs themselves and their contribution to the respective conservation programs were assessed in several ways, including questionnaires, interviews, and through direct observation.

Union of the Comoros

Quantitative evaluation of the EEP proved difficult because of infrastructure problems and a lack of local evaluators. Although nearly 100 questionnaires were distributed to prior recipients of educational outputs to evaluate their usefulness, response was extremely limited, with only six completed forms returned. Therefore, a qualitative approach was used that relied on direct observation of the use of educational outputs over 12 months and on semistructured interviews with approximately 50 users of the outputs. Table 1 summarizes the outcomes and impacts of the education and related conservation programs.

Outputs designed for interpretation by educators (particularly the slide packs and lesson plans) were less ef-

fective and more difficult to use than direct-to-user messages (such as the video, posters, stickers, and theatrical presentation). Use of the slide packs suffered from technological limitations because there were few slide projectors and suitable venues. Untrained speakers using the accompanying scripts had a tendency to extemporize excessively, losing their audiences' attention. Lesson plans were pitched at an inappropriate level—too high for most students to use directly and too low for educators.

The local-language video was widely used by Peace Corps educators, shown repeatedly on local television channels, and extensively copied. The video's major strengths included its uniqueness (most broadcast materials or videos are in French rather than Chidzouani and contain little local footage); its self-distributing nature (from copying and rental); its availability to a wide audience through local video clubs and television stations; and its flexibility (it could be used in its entirety or in installments).

The stickers and posters were readily displayed and prompted curiosity, serving as a useful vehicle to initiate discussion by environmental educators. The posters had lower durability and higher costs than the stickers and, because they were highly prized, were more frequently displayed away from public view.

The EEP outputs were of limited use on Mayotte without considerable adaptation because *P. livingstonii* is not found there. Additionally, political tensions have made the people of Mayotte sensitive to references to the Comoros as a collective term.

Infrastructure problems limited use of EEP outputs in more formal educational settings. Public schools and other government institutions were generally ineffective as message disseminators because of lack of capacity, frequent closures, and the high turnover rate of government personnel. The Peace Corps, which had a major role in environmental education in schools, withdrew from the Union of the Comoros in 1995. The number of private schools, where disruption is rare, has increased in recent years, with many students who can afford it now enrolling. Future EEPs should target these schools.

Access to the EEP was more effective at the village level, through the work of the touring workshops and local NGOs. Interviews in villages near roosts in 2001 revealed that the EEP had raised awareness about the existence of Livingstone's flying fox and the interdependence of bats, forests, and people.

The establishment and work of Action Comores (antenne Anjouan) was a major outcome in terms of capacity building. This NGO, with external help, prepared an action plan that outlined conservation recommendations for *P. livingstonii* for the next 5 years (Sewall et al. 2003). Population estimates for 2002 from the monitoring and surveying program are of 1200 bats from 20 roosts, with almost half of these roosts reported by Comorians as a result of the EEP. In addition, the EEP has provided information for the government to initiate legislation protecting *P. livingstonii* and its habitat. The successful establishment of protected areas relies heavily on village-level management, in keeping with a community-based conservation approach (UNDP 1997). Work has started on establishing a forest reserve for *P. livingstonii* on Moheli and on evaluating a site for a reserve on Anjouan (W. Masefield, personal communication). The successful establishment of the Moheli Marine Park in 2001, with community involvement in its management (UNDP 2002), shows the potential for future terrestrial equivalents. The EEP coincided with growing local environmental awareness in the 1990s and fostered considerable local pride in the uniqueness of *P. livingstonii*.

Pemba

A range of evaluation processes were used to assess the EEP. Table 2 summarizes the outcomes and impacts of the education and related conservation programs.

Evaluation of the 1992 EEP was conducted through direct observation and semistructured interviews with 92 students at 17 schools. A standard set of 13 open-ended, nonleading questions was used to determine knowledge of and attitudes toward bats and knowledge of *P. voeltzkowi* and its conservation. Specific questions were

also asked to determine the sources of this information. Seventy nine percent of students knew that bats were mammals, 78% had positive attitudes toward bats, and 67% cited seed dispersal and regeneration of forests—the key focus of the 1992 EEP—as the reason for their favorable opinion of bats. Only 12%, however, knew of the endemic status of *P. voeltzkowi*. Of the 92 students questioned, only 7 had attended the previous EEP. Of the 20 students who could explain where they had gotten their information, 16 had heard by word of mouth from friends and family, and only 4 had gained information from their teachers. The teaching packs provided in 1992 were not used and could not be located in any school. Comprehension of the poster's message was mixed among students who had seen it previously; 49% were able to explain it, but 24% had completely misunderstood it.

Interviews with members of one village revealed that the provision of information to the local teacher in 1992 had stimulated the direct protection of a local roost site.

Because this initial evaluation revealed word of mouth as an important means of information transfer, the 1995 EEP built on the use of students as ambassadors to spread information on bats within their community. Printed materials (leaflets and stickers) were simplified in their design and message and developed in the local language. Subsequent village visits revealed that the stickers and leaflets were displayed in villages adjacent to the schools where students received them. The logo on the sticker attracted attention to the project and the unique nature of the bats, and villagers asked direct questions about the issues raised in these materials. The video was also an invaluable aid in engaging audiences. Informal feedback from the village meetings in 1999 indicated that the villagers very much welcomed consultation and the opportunity to be involved in EEPs. To date there is no evidence of curriculum change that includes information on bats. This may result from the fact that the curriculum is established on Zanzibar (where *P. voeltzkowi* is not present) and lobbying of key authorities to change the curriculum is difficult.

The establishment of the community-based environmental clubs has had several direct conservation impacts. Bat protection campaigns have been developed within villages. Several clubs protect bats in graveyards near their villages, resulting in protection not only of the bats but also of vital areas of old-growth forest, which are associated with larger bat roosts (Entwistle 2001). At least one village changed local bylaws governing the capture of bats and implemented a ban on shotgun hunting of bats. In a series of local workshops, a consensus was reached on the need for long-term regulation of the hunting of this species.

Local participation in survey work and support of external scientists have helped to generate a more accurate population estimate of ~ 6900 bats (Entwistle 2001). The EEP tapped into a great local desire among students and villagers for more information on *P. voeltzkowi*, a

desire that was enhanced once its endemic status was recognized. These factors have greatly increased the ability of the DCCFF to support and promote conservation initiatives.

Rodrigues

The well-developed infrastructure and greater project funding on this island facilitated more formal evaluation of the EEP than was possible in either the Union of the Comoros or on Pemba, although direct observation was also used. Table 3 summarizes the outcomes and impacts of the education and related conservation programs.

To assess the bat education kits, pre- and post-treatment questionnaires covering the presentation and the students' attitudes about bats were given to four randomly selected students from each class visited (Jamieson 1996). Of 76 responses to each of 10 objective questions, more students answered correctly after the presentation than before, and for 7 of the 10 questions, this difference was significant (Jamieson 1996). Students learned from the lessons presented by the Philadelphia Zoo staff, despite problems resulting from language barriers, time limitations, and the students' unfamiliarity with the interactive teaching methods. Consultation with education personnel on Rodrigues during development of the kits was crucial to their effectiveness and to their relevance to established curricula.

Presentations also had an impact outside the classroom: zoo staff members were approached by appreciative parents whose children had been involved in lessons. Secondary impacts eventually reached the media and resulted in stories about the bats and the education kits on local radio and television. After the initial presentations, however, the kits remained unused for 2 years because of their inaccessibility and an overloaded school syllabus. Production of less elaborate and less expensive kits may have permitted wider distribution and resulted in greater opportunities for use.

Further evaluation of the use of education outputs by the community environmental educator indicated that students understood and could recall facts about the natural history and conservation of *P. rodricensis* (McDonald 1998). Of 103 replies, 73% of the respondents knew that *P. rodricensis* was endemic to Rodrigues; 54% made positive comments about bats; 8% made negative comments; 64% knew that *P. rodricensis* was endangered; and 43% knew that it was receiving international conservation attention. As a result of these evaluations, the educator developed additional outputs that used fewer technical terms and were written in the local language, and reinforced messages by setting up an "environmental education corner" in several schools.

The original bat-focused EEP resulted in the employment of the local community environmental educator, who now has a wider educational role that is at the core of

the Mauritian Wildlife Foundation's conservation policy. Local involvement and direction, through the work of the local community environmental educator in schools and village communities, has been the most effective outcome of the EEP, bringing about positive changes on Rodrigues through local knowledge and activity. Local participation in survey work and support of external scientists have helped to provide a more accurate population estimate of ~ 5100 bats (Powell & Wehnelt 2003). The foundation has also been prompted to establish two new forest reserves, primarily to encourage native flora, which are being used as feeding sites by *P. rodricensis* (V. Powell, personal communication). Rodriguans view their bat with pride, despite it being frequently considered a nuisance when it feeds on fruit crops.

Discussion

Before these EEPs began, there was little or no scientific knowledge of the ecology and conservation status of these fruit bat species and little local awareness of their uniqueness, potential ecological roles, and conservation status. Therefore, raising local awareness of these issues, through knowledge transfer, communication strategies, and a diverse range of outputs, was an important initial component of these EEPs, on which other education and conservation actions can be based.

Achieving outcomes from these education strategies initially depended on identifying, using, and building on the most reliable and appropriate local infrastructure available. In Pemba and Rodrigues, a stable and well-supported school system was used, but in the Union of the Comoros the more informal network established by Peace Corps volunteers and local Ulanga groups was used. All three EEPs demonstrated the importance of strategies focused on local village communities that had direct contact with bats, through proximity to roosts or feeding sites. These local communities were instrumental in informing and strengthening community-based environmental groups. This agrees with results from Gabon indicating that environmental education efforts aimed at community members in proximity to the focal species were more successful than those aimed at government agents (Thibault & Blaney 2001).

These EEPs demonstrated the importance of capacity building in the form of training and equipping local educators, who can then pursue the goals of the EEP. A local perspective offers the potential for increased relevance, appropriateness, and sustainability; provides integration into the local culture and thus better knowledge about local issues, attitudes, barriers, and opportunities; allows the EEP to be integrated into the local curriculum; facilitates more effective evaluation procedures; fosters personal investment in bringing about positive change; provides local continuity in the EEP; and results in a

reliable point of contact for outside conservation initiatives. Increased cost-effectiveness is also possible by, for example, enabling local educators to produce their own materials tailored to their own requirements.

The feasibility of such local capacity building is greatly enhanced by the existence of functioning formal educational networks. The unfavorable response to the EEP outputs for *P. livingstonii* on Mayotte and the inability to modify the curriculum that was set in Zanzibar to include issues on *P. voeltzkowi* showed the importance of local attitudes and appropriate content to EEP establishment.

All three EEPs fostered increased pride in the endemic fruit bat species. Padua (1994) found that local community members in Brazil became similarly proud of their natural legacy, notably black lion-temarins (*Leontopithecus chrysopygus*). Silvius (1997) and Sanz and Grajal (1998) reported that education efforts for the conservation of the Venezuelan Yellow-shouldered Amazon (*Amazona barbadensis*) made this parrot a focus of local pride and led to the declaration of this species as the official state bird in 1990. The EEPs we examined demonstrate that less charismatic animals, such as bats, can be useful as flagship species for wider scale environmental education programs if awareness-raising and educational activities are targeted at appropriate audiences (Entwistle 2000).

Another major outcome of these EEPs was their facilitation of other components in their respective multidisciplinary conservation programs. Increasing communication with government officials and NGOs has resulted in changes to local bylaws and national legislation and development of future conservation plans. All three EEPs have supported ecological research programs through training and support to local “parabiologists.” Equally significant, these EEPs have played a major role in providing accurate population estimates and frameworks for reliable population monitoring, particularly through active participation by NGOs and government organizations in these programs. Raised awareness in bat habitat areas has led to the discovery of new roosts in all three locations. Population estimates for all three species have gone from <200 individuals to ~ 1200 for *P. livingstonii*, ~ 6900 for *P. voeltzkowi*, and ~ 5100 for *P. rodricensis*, and this information has an important impact on future conservation policy. Castillo et al. (2002) similarly demonstrated in Mexico how EEPs can facilitate the use of ecological information in conservation management.

Conclusions

Most of the goals of the EEPs have been achieved. Conservation and education outcomes included increased awareness and understanding of conservation issues; improved knowledge of the status of the species; policy making and legislation development; strengthened commitment to conservation and a greater capacity to carry it out;

employment and empowerment of local educators; integration of environmental issues into the curriculum; establishment of active local environmental NGOs; and support for multidisciplinary conservation programs. Except for hunting, however, which has been reduced (but not stopped) on Pemba, these EEPs have been slow to have any significant impact on the major human-induced threat for these species—habitat loss. Addressing habitat loss is a complex issue in these three island groups, necessitating much larger social and economic reforms and individual behavioral changes through greater environmental awareness. Although most of the people currently involved in habitat destruction have few other options for survival, the EEPs, in the context of their multidisciplinary conservation programs, have supported the beginnings of modest habitat protection initiatives. They have also established a level of local awareness and a capacity for informed action that will facilitate further conservation impacts, if the larger social and economic issues preventing habitat protection can be addressed.

Although these three EEPs were developed independently, this collaborative evaluation will further improve their design, implementation, and effectiveness. Local educational initiatives supported by regional perspectives could improve conservation programs in many ways, including broadening the available knowledge base, exchanging human and technological resources, and accessing potential sources of funding (Fernández-Juricic 2000). The lessons derived from these initiatives (Table 4) may serve as guidance to anyone formulating an EEP to benefit endangered species in developing countries.

Given that each element of a conservation program, such as an EEP, requires a range of inputs and skills from ecologists to educators, it is important for conservation biologists involved in EEPs to study the environmental education literature (e.g., *Environmental Education Research* and *Journal of Environmental Education*). The publicizing of successful EEPs, particularly from developing tropical countries that hold great proportions of the planet’s biodiversity, should also be encouraged in the conservation literature (Wood & Wood 1985; Padua 1994; Norris & Jacobson 1998).

When species such as *P. livingstonii*, *P. voeltzkowi*, and *P. rodricensis* are listed as critically endangered, they face a probability of imminent extinction (IUCN 2003). In light of such urgency, conservation activities that provide rapid results must be given high priority. Environmental education programs may be overlooked in such cases because of a perception that they are complex and expensive to implement and that their concrete benefits are slow to accrue. These three EEPs, however, produced important conservation and education outputs, along with some conservation impacts. They show that even in challenging settings, with careful design and implementation, EEPs can directly benefit conservation in the short term, greatly improve the effectiveness of other components

Table 4. Common lessons applicable to environmental education programs (EEPs).

Importance of local involvement in and time spent researching the production of education materials; results in providing locally relevant content at the right level through the best delivery systems
Importance of time spent identifying the most appropriate technologies for delivering education materials; results in faster and more reliable dissemination of materials
Success of stickers, leaflets, and other low-unit-cost direct-to-user items that can be widely distributed and spark discussions with trained educators
Ephemeral nature of some high-unit-cost items easily co-opted by relatively few individuals, thus providing only limited and ephemeral benefits
Importance of using local language material in the multiple-language situations, material accepted more enthusiastically
Need for school-based education initiatives to reach a wide audience, and importance of identifying a curriculum need with training and education materials to address this; more effective than expecting local teachers to use externally developed materials in extracurricular activities
Importance of training local educators; allows for local development and production of materials wherever possible and has the potential to increase success of message transmission and cost-effectiveness
Need for community involvement in EEPs, given that local communities are likely to pose the greatest threat to the species through their actions and have greatest potential to change their behavior to reduce impacts
Importance of identifying/establishing suitable infrastructure for maintaining and reinforcing aims and objectives of education programs; should result in a more sustainable adoption of the EEPs
Need for thorough evaluation of EEPs (preferably built into original design), through whatever means local conditions allow, and use of this evaluation to modify and further develop EEPs; can contribute significantly to the improvement of EEPs
Cross-disciplinary impact of EEPs on other components of multidisciplinary conservation programs

of multidisciplinary conservation programs, and form a strong foundation for long-term, lasting conservation impacts.

Acknowledgments

The following organizations and individuals provided support in the Union of Comoros: Bat Conservation International; British Airways (assisting the Conservation Nature Roots Group); Bristol, Clifton and West of England Zoological Society; CARE-Comores; Centre Nationale de Documentation et de Recherche Scientifique des Comores; D. A. Mohamed; the Dayton-Wilkie Fund of the Bell Museum of Natural History; the Durrell Wildlife Conservation Trust; Fauna and Flora International; the government of the Union of the Comoros; the Institute of Zoology; the International Centre for Conservation Education; the Leverhulme Trust; the Marshall Aid Commemoration Commission; W. Masefield; M. Moutui (Action Comores [antenne Anjouan]); the U.S. Peace Corps; the People's Trust for Endangered Species; T. Pratchett; Project Conservation de la Biodiversité et Développement Durable aux Comores; the Richard Lounsbury Foundation; the Royal Geographical Society; Ulanga; the University of Aberdeen; the University of Minnesota Office of International Programs; the MacArthur Program; and the Conservation Biology Program.

The following organizations and individuals provided support in Pemba: A. Ely; Fauna and Flora International; the Lube Foundation; the People's Trust for Endangered Species; P. Racey; M. Abdalla, K. Said, M. and A. A. Mwiyni of the Sub-Commission for Forestry; M. Thabit of the Sub-Commission for Forestry in Zanzibar; the villagers of Mjini Ole; and the University of Aberdeen.

The following organizations and individuals provided support in Rodrigues: Air Mauritius; the AZA Bat Taxon Advisory Group and Rodrigues Fruit Bat Species Survival Plan; the AZA Conservation Endowment Fund; Bat Research News; Biodome de Montreal; British Airways (assisting the Conservation Nature Roots Group); Disney's Wildlife Conservation Fund; M. Drabik; the Folsom Children's Zoo; H. Jamieson and M. Ligouri of the Philadelphia Zoo; the John Ball Zoo Society Wildlife Conservation Fund; the Mauritian National Parks and Conservation Service; the Mauritian Wildlife Foundation; the Ministry for Rodrigues; the Oregon Zoo Foundation; the Organization for Bat Conservation; the Philadelphia Zoo's Conservation Fund; the Philadelphia Zoo Zoofari Club and Zoo Chapter of the American Association of Zookeepers (AAZK); the Portland chapter of AAZK; V. Powell; the Riverbanks Zoo and Botanical Garden; C. Flore of the Rodrigues Education Centre; the Rodrigues Forestry Division; Rodrigues Government Schools; Rodrigues Roman Catholic Authority Schools; Roger Williams Park Zoo's Sophie Danforth Conservation Biology Fund; D. Schaffer; Service System Associates/Volume Services America; the Sierra Club West Jersey Group; V. Smith; the Lube Foundation; and the Woodland Park Zoo's Conservation Fund. We also thank three anonymous referees for their valuable comments on the manuscript.

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