

Helping HELP with limited resources: The Luquillo experience[#]

FN Scatena^{1*}, JR Ortiz-Zayas² and JF Blanco-Libreros³

¹ University of Pennsylvania, Dept. Earth and Environmental Science, 240 S 33rd St. Philadelphia Pa.

² University of Puerto Rico, San Juan, PR

³ Universidad de Antioquia, Medellin, Colombia

Abstract

By definition the HELP approach involves the active participation of individuals from a wide range of disciplines and backgrounds, including representatives of industry, academics, natural resource managers, and local officials and community leaders. While there is considerable enthusiasm and support for the integrated HELP approach, a central problem for all HELP basins is how to effectively engage individuals and groups with few, if any financial resources. In the Luquillo HELP project we have managed this issue by focusing our efforts on holding small, public meetings and workshops with technocrats and managers who are engaged in local water resource management. To date several forums have been organised, including: technical meetings with the directors of natural resource agencies; presentations and panel discussions at the meetings of local professional societies, including the societies of Civil Engineers and Architects, the Commonwealth Association of Tourism, the Association of Builders and Developers, and the Puerto Rican Association of Lawyers. During these forums HELP specialists gave presentations and led discussions on how integrated watershed management can help resolve local problems. Because the audience are directly involved with these issues, they are quite responsive to these discussions and have often provided unique solutions to common problems. Technical workshops are co-sponsored by local municipalities – these day-long workshops are hosted by a municipality and include managers from other municipalities, the local water authority, and local community leaders. Additional activities include: technical advice on water infrastructure projects is given; there are educational exchanges between local and international students, scientists, natural resource managers, and community leaders; and synthesis publications relevant to integrated water resource management are produced. Other activities have included compiling oral environmental histories and organising watershed restoration activities. This paper describes these activities and discusses the benefits and costs of each approach.

Keywords: integrated water resource management, tropical mountains, Puerto Rico

Introduction

Both integrated water resource management (IWRM) and the HELP approach involve the active participation of individuals from a wide range of disciplines and backgrounds. This commonly includes representatives of industry, academics, natural resource managers, local officials and community leaders. How to effectively engage these individuals and groups with few, if any, financial resources is a problem that faces all HELP projects. In the Luquillo HELP project we have managed this issue by focusing our efforts on promoting information exchange via small, focused workshops with individuals who are at the front line of water resource management in the region. This paper describes these and other activities in an effort to provide information to other HELP basins facing similar logistical problems and financial constraints.

The Luquillo HELP project is a voluntary effort that was founded and is managed by the authors of this paper. While each author currently works at a university, all have held water-related positions on the island in industry and government positions over the past two decades and are involved in a range of IWRM activities and outreach efforts. The current HELP effort devel-

oped out of ongoing efforts and now involves a loose network of students, government officials, and formal and informal community organisations. All Luquillo HELP efforts are voluntary and although the group has been effective in finding support funds for specific activities, there are no established funds to support HELP activities. However, logistical and administrative support from the University of Puerto Rico, the USDA International Institute of Tropical Forestry, and US National Science Foundation (NSF) supported programs have greatly assist the effort. The primary advantage that these organisations and individuals gain from participating in the Luquillo HELP project is that it provides an objective and flexible framework for objectively discussing the islands water management problems. Moreover, Luquillo HELP acts as an unbiased conduit for exchange between researchers, resource managers and communities. Therefore an essential goal of the Luquillo HELP project is to: *maintain an unbiased flow of technical information and exchange related to water management in Northeastern Puerto Rico.*

Study area

Puerto Rico is the fourth largest island in the Caribbean. Over the last century it has been transformed from an agrarian based economy in a deforested landscape to an industrial and service based economy in a reforested and developed landscape (Grau et al., 2003). Today the island has over 428 inhabitants/km² and one of the highest population densities in the world (Puerto Rico Planning Board, 1995).

The Luquillo Mountains (LM) are the most prominent physiographic feature in Eastern Puerto Rico. They are also a

[#] Revised paper. Originally presented at the symposium 'HELP in Action: Local Solutions to Global Water Problems – Lessons from the South' which was held at the Emperor's Palace, Johannesburg, South Africa from 4 to 9 November 2007.

* To whom all correspondence should be addressed.

☎ 215-898-5724; fax: 215-898-0964;

e-mail: fnscat@sas.upenn.edu

major source of water and an important site for recreation, education, and research on tropical ecosystems. On an annual basis the LM supports as many as 700 000 recreationists, dozens of students and researchers, and supplies over 20% of the island's municipal water (Scatena et al., 2002). The upper elevations of the LM are managed by USDA Forest Service as the El Yunque National Forest (EYNF). The surrounding lands are under private ownership. No active timber harvesting occurs in or near the National Forest. The EYNF does support an educational visitor centre, recreation sites, municipal water intakes and telecommunication sites. The LM are also a United Nations Man and Biosphere Reserve, have Nationally designated Wild and Scenic Rivers, and are the site of long-term ecological research supported by the USDA Forest Service International Institute of Tropical Forestry, the University of Puerto Rico, and the US National Science Foundation (NSF). This long history of research provides an excellent scientific basis for promoting and developing IWRM. However, many researchers are concerned that their research is not being considered in land use decisions. Likewise, local natural resource managers are concerned that they do not have the information they need to make decisions regarding water resources or the impacts of land use management. Thus a major goal of the Luquillo HELP project is to promote the *exchange of information and ideas between academic researchers and water resource managers*.

The LM have a warm and humid subtropical climate that is influenced by orographic systems, easterly trade winds, hurricanes and other synoptic weather systems (Garcia-Martínó et al., 1996; Pike, 2006). Rainfall and runoff occur in every month of the year and increase with elevation. Annual precipitation can range from approximately 1 500 mm/yr near the coast to over 5 000 mm/yr in the uppermost cloud forests. The National Forest alone provides an average of 276 hm³ of water year for municipal uses (Scatena and Johnson, 2001). It is also home to over 400 species of plants and 143 species of terrestrial animals, fish, shrimp, and freshwater snails. Most of these aquatic species must migrate between the coastal zone and the mountains to complete their life cycles. Therefore a major goal of the Luquillo HELP project is to *promote and maintain the continuity and aquatic health of rivers from their headwaters to the ocean*.

Seven major rivers have headwaters in the LM. These rivers all have steep gradient, boulder and bedrock lined channels with step-pool morphology and water falls (Ahmad et al., 2003). Stream-water quality is excellent, and the rivers within the EYNF are considered to be the cleanest and most natural on the island (Santos-Román et al., 2003). While the headwaters of these rivers have been protected for over a century, and some areas have been protected since Columbus landed on the island in 1494, the lowlands support a mixture of urban, suburban, and agricultural land uses. In recent decades, land use in the periphery of the LM has changed drastically as agricultural lands have been abandoned and changed to forests or developed areas (Grau et al., 2003). The population in the LM area is projected to increase at an average rate of 0.86 % per year and by 2010 the area will have 293 000 inhabitants (Puerto Rico Planning Board, 2006). These increases in population combined with increases in the number of second homes and resorts have also increased the demands for the region's natural and aquatic resources.

By the early 1990s, it was estimated that on a typical day more than 50 % of the water draining the EYNF was appropriated for municipal uses before it reached the ocean (Scatena and Johnson, 2001). In 1995, the area's per capita water use was among the highest in the world at 732 l/cap-d (Ortiz-Zayas and Scatena, 2004). Unfortunately, water use efficiency is low and

nearly 42% of the water processed in water treatment plants is unaccounted for and lost to leaks either in the water distribution system, illegal connections, or in accounting errors. Today, the region faces nearly all the management issues that are commonly associated with urban hydrology, including those related to stormwater management, drinking water supply and wastewater management. The complexity of these issues is increased because of differences in the quality of water supply infrastructure between the new developments and modern resorts complexes and the aging water supply infrastructure of the older, and generally poorer, communities.

While the Luquillo region has abundant rainfall and numerous surface water bodies, there are limited opportunities for developing additional municipal water sources. Moreover, there is a lack of areas where dam can be built and relatively minor groundwater supplies (Ortiz-Zayas and Scatena, 2004). Most municipal water in the region is abstracted directly from streams, and is thus constrained by the temporal variation in stream flows and chemistry. While demand for municipal water supplies has increased, there has also been an increase in instream uses for recreation and the consequent need to maintain instream flows and water quality. Specific management goals include maintaining: the migration routes of aquatic populations, fishing resources, recreation, and the water quality of coastal beaches. Thus a major goal of the Luquillo HELP project is to *promote the information exchange needed to manage aquatic resources for multiple uses*.

Institutional structure for water management

Water on the island of Puerto Rico is in the public rather than private domain and is managed under the amended Puerto Rico Water Law of 1976. It is also within the auspices of multiple governmental agencies and organisations that operate at different spatial scales and with different emphasis. Thus a central focus of the Luquillo HELP project is to *assist and foment communication and exchange between these organisations and individuals involved with managing Puerto Rican water resources*.

Puerto Rico is a Commonwealth Territory of the United States. As such, island residents are subject to the environmental regulations of the US Environmental Protection Agency and other Federal organisations. Many Federal agencies are involved in the islands water management, including the US Geological Survey who monitors the islands water quantity and quality, the US Army Corp of Engineers who are responsible for navigable waters and wetlands, the US Fish and Wildlife Service who manage threatened and endangered species and wetlands; the Natural Resources Conservation Service, who assists farmers in implementing best land and soil conservation practices; and the National Forest Service and Park Service who are responsible for managing National Forests and Parks.

The Commonwealth Government is responsible for enforcing the islands environmental laws and in implementing the Puerto Rico Water Law. However several Commonwealth agencies are involved with different aspects of water management. Potable and municipal water is administered by one central water supply agency, the Puerto Rican Water and Sewage Authority (PRASA). The Commonwealth Department of Natural and Environment Resources (DNER) administer a water-permitting program to evaluate water development proposals under guidelines established in an island-wide water plan. Other local agencies involved with water management also include the Environmental Quality Board, the Electrical Power Authority, and the Departments of Agriculture and Tourism.

At the regional level the island is divided into municipalities, whose geographic area is typically defined by major rivers and commonly extends from the coast to the island main water divide. Individual municipalities range from large urban centres (e.g. San Juan) to smaller, dominantly rural areas. In all cases they are governed by an elected mayor. While only a few municipalities operate even small water supply systems, they are responsible for managing municipal waste and are responsible for developing municipal land-use management plans.

Existing outreach activities

Because of the importance in water resource management, and the importance of education in the island's culture, there are many ongoing outreach and information exchange efforts that are relevant to the goals of IWRM and Luquillo HELP project. Thus a major goal for the Luquillo HELP project is to *complete and support existing educational outreach programs*.

Ongoing activities that are aimed at informing the general public about water related issues include exhibits and events at schools and public shopping areas. Many of these events are done in coordination with events like Earth Day and World Water Week. These are often held at large shopping centres that provide space and logistical support for the events. Many Federal and Commonwealth agencies sponsor have information centres at these events where employees provide literature and advice. Private companies that manufacture or sell solar hot water heaters, water tanks and purification systems and other water-related items have also participated and have assisted in sponsoring these events.

General public outreach has also been accomplished via special local television programs and radio shows that are dedicated to the regions water resources and environmental health. Because of their scenic beauty and their importance to the islands residents, the local media has always been interested in developing Luquillo-based programs. These programs have followed the flow of water from its interception as cloud water to its entry into the ocean, filmed the migration of aquatic organisms from the coast to the headwater streams, and documented illegal fishing and dumping.

Puerto Rico has also been blessed with a number of programs designed to engage local school children in environmental issues. Many of these were initiated by the efforts of a few individuals who started their efforts with no or limited funds. For example, the International Institute of Tropical Forestry has been engaging local high schools in basic forest ecology research for over 30 years. These low cost efforts involved working with teachers and students to establish forest monitoring plots and simple climate stations in or adjacent to school yards. Once these study areas are established, teachers work with successive classes of students to re-measure the plots and monitor forest development over time. Ideally, the results from these measurements are used in the class-room for assignments in applied mathematics, data management, and science.

Over the years these school yard efforts have included a range of activities like bird counts, inventories of invasive species, stream monitoring projects, and island wide annual science fairs. The most successful projects have generally involved periodic measurements using basic equipment that the entire class can use. Projects that require continuous measurements using sophisticated instruments that only a few students can use have been less well received. Having a strong and continuous relationship with the teachers is also essential to the success of these programs. Because teacher recruitment can be problem-

atic, some programs have provided funds for substitute teachers or teacher aids, equipment and travel (Dailey, 2005). Some sponsored programs have teacher workshops that provide credits toward advanced teaching certificates.

A variety of programs also exist for engaging university students and teachers in IWRM related efforts. These include the NSF Research Experience for Undergraduates Programs and exchange programs for elementary and high-school teachers. These programs typically pair students with individuals conducting research in the National Forest. While many, if not most, of the participants in these programs are interested in working on IWRM related topics, language boundaries, their short duration (1 to 3 months), and logistical issues often limit their involvement to specific components of the research projects that can be undertaken in or near the EYNF. Nevertheless, they have provided invaluable information to technical aspects of the problems.

The Luquillo HELP approach

Because of the existing public outreach activities described above, the Luquillo HELP project decided to focus its efforts on promoting interactions between research scientists and environmental managers who work with the local municipalities and regional offices of the Commonwealth agencies. This emphasis was selected because these environmental managers were not being explicitly involved in other outreach efforts. Nevertheless they are at the forefront of environmental management in the region and their involvement insures that there will be a strong feedback loop between the generation of information and its use. The Luquillo HELP project also recognise that genuine social interaction requires a considerable investment of time and energy to develop personal relationships based on trust and mutual exchange of information (Rhoads et al., 1999). Therefore, our focus has been on developing long-term relationships by providing periodic activities and exchanges, rather than single event based interactions. While some of these efforts were initiated before the formal establishment of the Luquillo HELP project they have all become an integral part of the Luquillo strategy and can be grouped into the 6 interrelated activities described below.

Technical meetings with the directors of natural resource agencies

In the mid to late 1990s island wide droughts and water management issues were creating considerable tension across the island. At the same time aquatic research was documenting the migration of aquatic species, increased instream recreation, and the importance of environmental instream flows. To address the overall issue of how to manage multiple demands on aquatic resources, several public meetings were organised for the executives of the major agencies who were directly or indirectly involved with water management on the island. The goal of these meetings was to insure that each agency was knowledgeable of the issues and opportunities at hand. At each meeting formal presentations were made by local and visiting academics, environmental lawyers, and consulting engineers who were engaged with water resources. Each agency also had the opportunity to discuss their water management activities and the problems they face. These first meetings were media events that were widely covered by local television and radio stations. Their focus was on information sharing and fact-finding rather than determining responsibility for past or present failures.

In comparison to other Luquillo HELP activities, these workshops take considerable more effort to organise and coordinate. Furthermore because they involve the participation of many extremely busy Agency heads, they occur much less frequently. Nevertheless, because agency heads change every few years, the Luquillo experience also suggests that these high-level forums are needed every few years. When they do occur, impartial organisations like HELP are needed to organise the events to insure they have wide and impartial representation. Specific public commitments that have developed, and have been honoured subsequently from these activities include:

- Commitments to hold public forums before any large water infrastructure project is approved
- Commitments to modernise the water permit process
- Commitments to evaluate and consider environmental flow needs
- Commitments to establish interagency technical committees to address specific management issues, like coastal zone protection, marina management, and riparian buffer design.

Presentations and panel discussions at the meetings of local professional societies

In the initial stages of promoting HELP concepts on the island, it was apparent that involving local professionals was essential to understanding and solving the island's water management problems. In an effort to engage this community, presentations and panel discussions have been held at the monthly meetings of the local professional societies. These organisations have included the Puerto Rican Societies of Civil Engineers and Architects, the Commonwealth Association of Tourism, the Association of Builders and Developers, the Puerto Rican Association of Lawyers, and interagency meetings on disaster mitigation, security, and environmental issues. During these forums HELP specialists give 30 min slide presentations and led 30 min discussions on how IWRM can help solve local water resource problems. Because much of the audience are directly involved or impacted by these issues, they have always been responsive to these discussions and often provide unique insights and solutions to common problems.

Technical workshops sponsored by local municipalities

After initial meetings with agency heads and professional societies, the Luquillo HELP project began focusing efforts on day-long workshops with municipal managers, representatives from the regional offices of the water authority, and local community leaders. Although these managers confront similar problems, they rarely exchanged information in a formal or consistent basis before these HELP workshops. With the assistance of the Luquillo HELP project the municipalities now sponsor periodic meetings on Luquillo water issues.

The first workshop was held in San Juan in 2005, was co-sponsored by the Global Water Partnerships and attended by approximately 30 individuals. As is an island tradition, lunch and coffee breaks were provided. While this and all the workshops have been open to the public, formal letters of invitation were sent to Municipal Mayors and key environmental managers. Attendees have included water plant operators, local educators, state park managers, regional representatives from the Commonwealth and Federal agencies, and community leaders. The meetings typically start with a formal introduction by the local

mayor or designated official who is sponsoring the meeting. The morning sessions are then focused around short presentations by the local municipalities and resource managers. These presentations are followed with working groups that address selected questions and broad themes developed from previous meetings. These meetings are typically attended by 15 to 20 individuals, over half of which have attended previous meetings. There is also a call for agenda items before the meeting and an assessment at the end of each meeting.

The major cost of these meetings to the Luquillo HELP project has been associated with their initial organisations. This included sending formal invitations to the municipal mayors, identifying local community leaders, and in providing lunches and educational materials at the first meeting. After the first meeting, each municipality agreed to sponsor subsequent meetings and the costs and logistic responsibilities of the Luquillo HELP project have decline. Furthermore, because the meetings are held in municipal buildings and do not require substantial travel or other costs, they are essentially self-funded.

Our experience after several of these meetings indicates the importance of the following:

- While the meetings are open to the public, they are technically orientated and not a designed as a forum for local groups to promote their selective agendas or projects. Therefore having HELP personnel involved in developing the agenda and moderating the meeting is recommended and appreciated by the hosting Municipalities.
- Meetings should be frequent enough that interpersonal relationships can develop, but not so frequent to become burdensome or repetitive. In the Luquillo area there are 8 municipalities involved in these meetings. At a rate of 2 meetings per year, each municipality only has to sponsor a meeting once every 4 years. To date this level of activity appears adequate and sustainable.
- Having workshop assessments and maintaining a record of key recommendations of the working groups is needed to provide continuity and avoid unnecessary repetition between meetings. Because each meeting is sponsored by different a Municipality, this role has been primarily managed by Luquillo HELP personnel. Ideally, short summaries of each meeting are developed and sent to the group when the agenda is being planned for the next meeting.
- The opportunity for informal interactions and exchanges is a key element of these meetings. One of the common comments after the initial meetings was that there were 'too many talks and not enough time to interact'. This has been addressed by having fewer talks, longer moderated question periods, more working groups, and by providing ample time for group lunches.
- Scheduling meetings during times of year when the schedules of the municipal employees are most flexible. Avoid holding meetings that conflict with elections and other major municipal events.

Technical advice

Providing technical advice to water infrastructure projects has not only proven an invaluable way to share and integrate knowledge but has also resulted in a range of excellent educational and research projects. The involvement of the Luquillo HELP project has varied from providing formal written comments on project designs and impact analysis to the active participation in the actual design and management of specific projects. Several of these interactions have ultimately provided the basis for

graduate level research projects and peer reviewed publications. Specific examples include:

- Development of an instream water-extraction system that extracts stream water without impeding aquatic migrations or channel margin habitats (Benstead et al., 1999).
- Development of off-stream reservoirs that store storm flow while allowing for the migration of river fauna and a reduction in reservoir sedimentation (March et al., 2003).
- Development of water extraction schedules that coincide with the life cycles of migrating aquatic organisms (Scatena, 2001).
- Assessing the environmental impacts of illegal fishing (Greathouse et al., 2005).
- Assessing the impacts of bridge design and stream channel modifications on the migration of aquatic species (Blanco et al., 2005; 2006)
- Hydrologic models and analysis (Garcia et al 1996, Rivera-Ramirez et al., 2002; Pike, 2006)
- Island wide water quality characterisations (Santos-Roman et al., 2003) that have provided the basis for inter-basin comparisons.
- Analysis of wetland and riparian zone vegetation that have provided the basis for restoring and managing the terrestrial and aquatic interface (Kent et al., 2002; Scatena, 1990).
- Selection of focus sites for the river conservation program currently being considered by the Puerto Rico Water Management Plan. This program is working to protect ecologically sensitive or unique river segments on the island.

Educational exchanges

Promoting internships, international exchanges, and student projects has always been an essential component of the Luquillo HELP project. These exchanges include both traditional exchanges between local students and scientist's as well as non-traditional exchanges between international visitors, school groups, and local citizens. In a few cases, the Luquillo HELP project has also help individuals obtain travel funds and compensatory time from Commonwealth agencies and private consulting companies that has allowed them to attend international meetings on IWRM. The project has also had opportunities to host international exchanges. In the recent past collaborators from Guatemala, Mexico, Dominican Republic, Costa Rica and elsewhere have visited the LM. These international visitors are self funded but usually stay free of charge at the field stations operated by the USDA Forest Service or the University of Puerto Rico. While the Luquillo HELP project does not accrue direct costs with these visits, time is required to organise their visits and coordinate their interactions with relevant people. Fortunately, these visits are usually in the summer when the field stations are full of activity. The local community has also always been willing to share experiences. An essential strategy in all of these exchanges has been to engage early and mid-level managers who do not have opportunities to attend professional meetings.

Synthesis publications

Over the past decades the Luquillo HELP project has worked with private individuals, the International Institute of Tropical Forestry, and the Luquillo LTER program to produce several widely used publications that synthesise available information on local water issues. These publications are focused on providing a general audience with basic information on water problems

and solutions. Examples include an overview of the islands water resources (Lugo and Garcia 1996), ecologically based children books, and educational software. While the Luquillo HELP project does not provide funding for these efforts, it does assist in their development and help insure that the scientific basis of IWRM is well represented.

Two features characterise these publications, and make them some of the most demanded publications produced by the Luquillo research community. First, they were all developed to meet a specific need that was identified through discussions and interactions with the larger community. Secondly, they are factual and data rich, but understandable for the general public. One editorial technique that has proven useful in these efforts is to organise the publications around a series of commonly asked questions, like 'How much water does the average household use' or 'What happens to waste water once it leaves my house.' Most of the information for these publications exists in various technical publications but is not readily accessible to the general public. While there can be costs associated with publishing these publications, it has been our experience that if the product has a well defined audience, funds for publications are relatively easy to obtain. In some cases, like Children's book, profits can be accrued by selling the books. Examples of specific publications used in Luquillo and elsewhere include:

- General information publications on water use, land management, urban vegetation
- Children publications on the ecology of local streams and forests
- Class room material or the impacts and benefits of large infrastructure projects being proposed or developed in a region
- Educational web sites that provide links to local and regional environmental resources
- Collections of student projects developed in conjunction with educational exchanges and school yard programs. These publications are typically edited collections of papers and extended abstracts from student research projects, science fairs, and educational workshop. Individual issues typically have a IWRM theme and are distributed locally and electronically. Unfortunately they do require some professional editorial support and can cost several thousand dollars to produce. Nevertheless, they can provide an invaluable historic record of environmental change and are a highly visible outlet that demonstrates both individual and community involvement.
- Technical publications that document past and future environmental change in the region. In the Luquillo region these publications have documented the change from a deforested agrarian landscape to a landscape covered by secondary forests (Grau et al., 2002), historic uses of forest resources (Garcia et al., 1994), land use impacts on stream flow (Wu et al., 2006; 2007), and differences between actual land use and zoned land use. These publications have not only been extremely useful for putting current land uses into perspective, they also demonstrate the potential future impacts of current actions.

Miscellaneous activities:

While the following list of activities has not received direct assistance from Luquillo HELP, they have been successfully used in the LM and are potentially applicable to HELP basins elsewhere. These activities include:

- Developing oral environmental histories: compiling the observations of long-term residents in an area can be a valuable tool for understanding the impacts of past land use and communicating the importance of current activities on future generations. Video recordings of conversations with residents can be an easy and inexpensive way to record these environmental histories. In Puerto Rico these recordings have documented historic farming practices, the impacts of historic hurricanes and droughts, and the historic uses of certain native plants. In some cases these recordings have subsequently been used in museum exhibits and television programs. In all cases, they have provided an excellent way to help the community to understand environmental changes within the region.
- Sponsoring watershed clean-up and restoration activities. These are typically day long activities where volunteers help in a range of activities that can vary from trash removal to tree planting or ecological restoration. Because local municipalities are ultimately responsible for waste disposal and the maintenance of public recreation areas, it is relatively easy to obtain their direct assistance in organising and supporting these efforts. In Puerto Rico some of the most successful beach and park clean-ups efforts are annual events that are held at the same time each year. This continuity not only helps build a sense of community but also reduces the logistic costs and potential time conflicts with other efforts.
- 'Adopt a River' maintenance programs. These efforts have been adapted from the highly successfully 'Adopt-a-Road' program and provide opportunities where companies or organisations help support the maintenance of a local river or water source. Activities include sponsoring annual river clean-ups, riparian planting, and habitat improvement. The idea of expanding and integrating these programs into a island wide river conservation program that focuses on ecologically sensitive or unique river segments is currently being considered in the Puerto Rico Water Plan and can be regarded as a direct evolution of this type of program.
- Involvement with local environmental based community groups. Informal community groups have often been organised to address a particular problem, like poor water service in a community or the development of urbanisations, resorts or highway expansions. The efforts of several of these groups have been invaluable in documenting and understanding water management issues in the regions. For example, these groups have actively monitored the frequency of water service, documented broken water pipes, and monitored recreational use. In some cases these records have been used in legal court cases and have been widely reported by the local media. Many of these groups have contacted HELP to assist them with their efforts. While the Luquillo HELP group does openly provide technical information to all relevant groups it is been extremely careful to maintain objectivity and neutrality regarding specific projects.

Future directions

In conclusion the Luquillo HELP program has been guided by several overriding goals. These include helping to:

- Maintain an unbiased flow of technical information and exchange related to water management
- Exchange information and ideas between academic researchers and water resource managers

- Promote and maintain the continuity and aquatic health of rivers from their headwaters to the ocean
- Complement and support existing educational outreach programs.

The program's greatest successes have occurred when it provided structured activities that allowed stakeholders to freely exchange information on specific problems. While many of these activities take time to develop, they can be initiated with limited financial resources. Existing research and education programs can also be adapted to include an IWRM approach. Nevertheless, they cannot be accomplished without the logistical support of established organisations. Future challenges include developing objective metrics of success and finding mechanisms to promote long-term maintenance interactions and the unbiased flow of information.

Acknowledgement

This paper, and the entire Luquillo HELP project, would not have been possible without the continued support of the Institute of Terrestrial Ecosystem Studies of the University of Puerto Rico, the USDA Forest Service International Institute of Tropical Forestry, the Global Water Partnership, and the NSF supported Luquillo LTER program and Biocomplexity project.

References

- AHMAD R, SCATENA FN and GUPTA A (1993) Morphology and sedimentation in Caribbean montane streams: Examples from Jamaica and Puerto Rico. *Sediment. Geol.* **85** 157-169.
- BENSTEAD PJ, MARCH JG, PRINGLE CM and SCATENA FN (1999) Effects of a low-head dam and water abstraction on migratory tropical stream biota. *Ecol. Applic.* **9** (2) 656-668.
- BLANCO JF and SCATENA FN (2005) Floods, habitat hydraulics and upstream migration of *Neritina virginea* (Gastropoda: Neritidae) in Northeastern Puerto Rico. *Caribb. J. Sci.* **41** (1) 55-74.
- BLANCO JF and SCATENA FN (2006) Hierarchical contribution of river-connectivity, water chemistry, hydraulics, and substrate to the distribution of diadromous snails in Puerto Rican Streams. *J. N. Am. Benthol. Soc.* **25** (1) 82-98.
- DAILEY S (2005) *Teacher Recruitment Appendix 2. Handbook for LTER Education*, 2005. <http://schoolyard.lternet.edu/LTERedu-Handbook.pdf>.
- GRAU HR, AIDE TM, ZIMMERMAN JK, THOMLINSON JR, HELMER E and ZOU X (2003) The Ecological Consequences of Socioeconomic and Land-use Changes in Postagriculture Puerto Rico. *BioSci.* **53** (12) 1159-1168.
- GARCÍA-MONTIEL D and SCATENA FN (1994) 'The effect of human activity on the structure and composition of a tropical forest in Puerto Rico.' *Forest Ecol. Manage.* **63** 57-78.
- GARCÍA-MARTINO AR, SCATENA FN, WARNER GS and CIVICO DL (1996) Statistical low flow estimation using GIS analysis in humid montane regions in Puerto Rico. *Bull. Am. Water Works Assoc.* **32** (6) 1-13.
- GREATHOUSE EF, MARCH JG and PRINGLE CM (2005) Recovery of a tropical stream after a harvest-related chlorine poisoning event. *Freshwater Biol.* **50** 603-615.
- KENT R, ODUM HT and SCATENA FN (2000) Eutrophic overgrowth in the self-organization of tropical wetlands illustrated with a study of swine wastes in rainforest plots. *Ecol. Eng.* **16** 255-269.
- LUGO AE and GARCÍA-MARTINÓ A (1996) Cartilla Del Agua Para Puerto Rico. *Int. Inst. Trop. For.* **10** (1-3) IIS 1940-1148.
- MARCH JG, BENSTEAD JP, PRINGLE CM and SCATENA FN (2003) Damming tropical islands streams: Problems, solutions, and alternatives. *Biosci.* **53** (11) 1069-1071.
- ORTIZ-ZAYAS JR and SCATENA FN (2004) Integrated water resources management in the Luquillo Mountains, Puerto Rico: An evolving process. *Int. J. Water Resour. Dev.* **20** (3) 387-398.

- PIKE AS (2006) Application of digital terrain analysis to estimate hydrological variables in the Luquillo Mountains of Puerto Rico. In: *Proc. 5th FRIEND Conf. Climate Variability and Change – Hydrological Impacts*. November 2006, Havana, Cuba. *IAHS Publ.* **308** 81-85.
- RHOADS BL, WILSON D, URBAN M and HERRICKS EE (1999) Interaction Between Scientists and Non Scientists in community-based watershed management emergence of the concept of stream naturalization. *Environ. Manage.* **24** (3) 297-308.
- RIVERA-RAMIREZ HD, WARNER GS and SCATENA FN (2002) Prediction of master recession curves and baseflow recessions in the Luquillo Mountains of Puerto Rico. *J. Am. Water Resour. Assoc.* **38** (3) 693-704.
- SANTOS-ROMÁN DM, WARNER GS and SCATENA FN (2003) Multivariate analysis of water quality and physical characteristics of selected watersheds in Puerto Rico. *J. Am. Water Resour. Assoc.* **39** (4) 829-839.
- SCATENA FN (1990) Selection of riparian buffer zones in humid tropical steepplands. In: RR Ziemer, CL O'Loughlin and LS Hamilton (eds.) *Research Needs and Applications to Reduce Erosion and Sedimentation in Tropical Steepplands: IAHS-AISH Pub. No.* **192** 328-337.
- SCATENA FN and JOHNSON SL (2001) Instream-Flow Analysis for the Luquillo Experimental Forest, Puerto Rico: Methods and Analysis. USDA Forest Service General Technical Report IITF-GTR-11. 30 pp.
- SCATENA FN (2001) Ecological rhythms and the management of humid tropical forests: Examples from the Caribbean National Forest, Puerto Rico. *For. Ecol. Manage.* **5528** 1-12.
- WEI WU, HALL CAS and SCATENA FN (2007) Modeling the impact of land use change on the stream flows at the meso-scale watershed level in North-Eastern Puerto Rico. *Hydrol. Proc.* **V21** (DOI: 10.1002/hyp.6515).
- WEI WU, HALL CAS, SCATENA FN and QUACKENBUSH LJ (2006) Spatial modeling of evapotranspiration in the Luquillo Experimental Forest of Puerto Rico using Remotely-sensed data. *J. Hydrol.* **328** 733-752.
-