Monkey River Community Monitoring Program: A Preliminary Assessment

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Abstract: Monkey River Community Monitoring Program

Community natural resource monitoring is a low-cost monitoring alternative with high social returns. As a conservation strategy it is particularly useful in developing countries where internal funding is often scarce for environmental monitoring. Belize, Central America is one such country with heavy budget constraints, a young Department of Environment, and heavy pressure from foreign capital to develop hind for export-agriculture. Rivers and the organisms that use them often pay the price for irresponsible agricultural practices. The Monkey River catchment in southern Belize is no exception. Pilot riparian area assessment has shown significant riparian forest clearing by banana developers in the mid-reaches of the river. With riparian forests absent, substantial amounts of soil, macronutrients, and pesticides are entering the channel unimpeded, impacting downstream reaches and the coastal zone. In conjunction with a proposed Biosphere Reserve, community monitoring of the Monkey River will (1) provide river data for adaptive management of the proposed Biosphere Reserve, (2) involve local communities in the natural resource management process, and (3) provide data necessary to improve water quality and encourage better land use practices. Part 1 of this paper explores physical, socioeconomic, and conservation management aspects of the Monkey River catchment providing a background for Part 2 – program design considerations for sampling physical, biological, and chemical stream characteristics as well as human health. Realistic limitations and project feasibility are discussed in the summary.

Monkey River Community Monitoring Program

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List of Acronyms Used:

BFREE - Belize Foundation for Research and Environmental Education
BCES - Belize Center for Environmental Studies
BGA - Banana Growers' Association
MBCD - Meso-American Biological Corridors Project
MMMAT - Maya Mountain - Marine Area Transect
MRMP - Monkey River Monitoring Program
SDA - Special Development Area
UCB - University College of Belize

Introduction: Monitoring for the Protection of Aquatic Resources

The document is intended to serve as a preliminary assessment for the development of a monitoring program for the Monkey River watershed in southern Belize, Central America. It is hoped that the information herein will serve as a reference during the planning stages of such a project.. The need for monitoring of the Monkey River is pressing for multiple reasons. Heyman *et al.* recognize this fact in assessing the Maya Mountain - Marine Area Transect (MMMAT), a functionallandscape grouping (including the Monkey River catchment) currently receiving concentrated conservation focus. In their paper *Maya Mountain - Marine Area Transect: A Synthesis to Assist in Integrated Planning and Management* (1995) they recommend "riverine hydrology and water quality studies ...sediment loading, and riverine water quality analysis ... agrochemical testing ... discharge rate monitoring and modeling."

It is within the MMMAT planning initiative that a community monitoring program in the Monkey River Watershed fits best.. Briefly, the MMMAT is being targeted for planning and management using UNESCO Biosphere Reserve Principles. The MMMAT is functionally a grouping of six catchments that drain into Port Honduras in the coastal zone. According to Heyman *et al. (1995)*, "Port Honduras represents the core of a naturally functioning, highly productive ecosystem where watersheds support coastal wetlands and thus support near shore fisheries production." Of the six watersheds that drain into Port Honduras, the Monkey River drainage is the largest and also the most heavily impacted. Intensive export-oriented banana production is the cause of the majority of pollution being carried to the coastal zone by the Monkey River. Sedi!TIentation, macronutrient and pesticide runoff, and riparian forest clearing are impacting both the lotic and coastal systems significantly.

Human populations in the drainage are also impacted heavily. The largely refugee and immigrant labor force ("economic immigrants") for the plantations live adjacent to banana fields in the fallout of multiple pesticide spraying sorties weekly. Living conditions are deplorable, health services inadequate where existent, and groun9water reportedly contaminated. Resettlement efforts have been complication-ridden due to poor project planning and little logistical support of labor families to move their residences. The need for human health assessment in banana growing areas is overdue.

Banana growing practices are indirectly visiting impacts upon coastal communities by undermining the economic viability of marine fisheries, decreasing the aesthetic value of both the river and the sea as tourism attractions. This represents an inherent conflict of interests within Belize development schemes between improper upstream agricultural deyelopment and downstream non-agricultural activities. Products from banana cultivation in upstream areas of the Monkey River watershed undermine fisheries productivity by decreasing'productivity of primary producers in the coastal/marine ecosystem (impacting higher trophic levels) and potentially decreasing juvenile coral survival and settlement.. Reduced coral populations could make the area less desirable as a tourist attraction. Both fisheries and tourism play important roles in Belizean economic development schemes. In avoiding conflicts over land use violations by the banana industry, the Government of Belize sacrifices other cornerstones of Belizean economic development, perhaps weafening the economic structure as a whole.

Given the importance of commercial banana production to the meager Belize economy, attacks on the banana industry by conservation organizations (often themselves in need of government support) are politically complex. Commercial agricultural development is a political-economic reality in Belize that is unlikely to go away any time soon. Accepting this, the conservation community must encourage best management practices in the industry to minimize the environmental impact of development projects. At a minimum, developers must be brought to compliance with Belize natural resource legislation, voluntarily or legally. Objective data collected in a community river monitoring format could be used as leverage to attain such compliance.

Indeed, inhabitants of agricultural areas and downstream communities have the most to lose from continued irresponsible development activities. For this reason communities within the catchment are a natural source of energy for river monitoring. Put simply, their livelihoods, and sometimes their lives, are at stake. This point is well illustrated by recent events in the upper Sibun River watershed regarding the citrus development activities of plantation manager David Hale are testament to the effectiveness of community monitoring programs. In opening land for citrus, Hale violated the National Lands Act of 1992 by clearing riparian forest into the Sibun River and clearing into the adjacent Sibun River Forest Reserve. The community-based Sibun River Watershed Association reported this violation, prompting a stop work order by the Department of Environment, and a restoration order for the lost riparian habitat-one of the first such projects in Belize land use history (Boles, pers. comm.). Hale must also now work cooperatively with the watershed association with future development activities. The Sibun River Watershed Association stands as a model to start other such programs in Belize.

Through a partnership between the Belize Foundation for Research and Environmental Education (BFREE) (located in the upper Monkey River catchment) and the international conservation organization Lighthawk, more than 30 individuals from around the Monkey River watershed have flown "conservation missions" to survey the river from a new spatial dimension in a single propeller airplane. Such conservation missions became the basis for the establishment of the Sibun River Watershed Association in central Belize. BFREE took this opportunity to introduce community members to watershed ecology and ideas of bioregionalism. For many, such flights are dramatic experiences-seeing the beauty of the river, the development impacts on the forested landscape, and the brown stained sediment plume reaching downstream from an entirely new perspective. Such experiences are the foundation for a future Monkey River Monitoring Program.

A community-supported Monkey River Monitoring Program will provide needed data to regional land planners; improve environmental education through learning of river ecology and monitoring techniques; and provide community participation in the land management process. Types of data collected by community members will include biological and chemical indicators of stream health as well as physical variables such as channel cross-section, and longitudinal profile, peBble count, and discharge. Such data can be used to.monitor trends in fluvial and geomorphic conditions, to assess stream and watershed response to management, and to contribute baseline data to regional, national, and international databases (Harrelson *et al.* 1994). An inevitable step in the data collection process is education of aquatic ecology and river monitoring techniques. Such an exchange of technical information would assuredly be two way as conservation educators could use the classroom as a way to tap into local knowledge of river natural history. The UNESCO Scientific Advisory Panel for Biosphere Reserves considers that reserves should be viewed as "demonstration sites of harmonious, long-lasting relationships between man and the natural environment" (UNESCO 1987). A community-based river monitoring program has the potential to significantly forward this goal in the MMMAT.

This paper is divided into two parts. Part 1 presents background information for consideration in the planning of a Monkey River Monitoring Program. This includes a physical description of the catchment, a discussion of ecological linkages between functional elements in the landscape, an overview of resource use in the Monkey River watershed, socioeconomic profiles of communities in the drainage, and a SUllllI).ary of existing management initiatives relating to the area. Part 2 considers a low-cost monitoring program for the Monkey River. This program will be designed to provide physical data for long-term study of river processes and specific sampling techniques to assess the impact of fertilizer, sediment, and pesticide runoff into the lotic system; ensure upkeep of tilapia *(Oreochromis mossambicus)* containment mechanisms at the aquaculture facility on the Swasey Branch; and to potentially assess pollution from human waste and effluent from the aquaculture facility.

There are several limitations to this paper that should be noted. Due to the obscurity of much of the literature produced on Belize (most of which stays *in* Belize) several sources are relied upon heavily-most notably Heyman *et al.* (1995). Similarly, current maps, remote sensing data, and socioeconomic information are difficult to obtain from the United States and communication with remote villages in southern Belize is difficult and expensive at best. Given these limitations, this work should be considered a starting point for a project that will ultimately necessitate input from numerous sources including community members, aquatic science professionals, non-governmental organizations, and government agencies alike.

Part 1: The Monkey River Watershed

1.1 Physical Description of Study Area

Located in Belize's (Fig. 1.1) southernmost Toledo District, the Monkey River catchment drains 1,292 km^2 (499 mi^2) of land area, stretching more than three quarters the width of the country (Fig. 1.2). The trunk stream draws water and sediment from three subcatchments, the Bladen Branch, the Swasey Branch, and the Trio Branch. The river flows through all of the four major landforms found in southern Belize including: (1) the Maya Mountain higWands; (2) karstic limestone relief; (3) rolling and undulating lowlands; and (4) coastal flatlands (Heyman *et al. 1995).*

The quartz-rich igneous rock and Paleozoic marine sedimentary rocks the Maya Mountain highland area are drained by headwaters streams of both the Bladen and Swasey Branch. The area is known for its heavily dissected and steep slopes, a fact that has historically protected it from exploitation. The soils in this area are nutrient poor and highly erodible, supporting a mixed highland forest consisting mostly of palms, tree ferns, oaks, and pine trees. Erosion under the forest cover is significant with bulky boulders and cobble being deposited in upland streams and minor amounts of clay making it in suspension to the coast (Heyman *et al. 1995).*

Flanking the Maya Mountain highlands is an area of rugged karstic limestone relief consisting of Cretaceous period limestone. The soils here are high in fertility, but thin and subject to erosion. The main erosion product is black smectoid clay whichjs often filtered out passing through the deeply fissured limestone before making it to the river. Vegetation in this area is moist to wet tropical broadleaf forest.. Removal of natural forest cover here expedites surface runoff and impedes ground water recharge (Heyman *et al. 1995).*

The area of steep karstic relief merges with hilly to undulating lowlands carved from Tertiary aged calcareous marine sedimentary rocks. In hilly art:(as,soils are shallow, red-brown clays and clay loams that erode moderately under forest cover and more readily when vegetation is removed for milpa (slash and burn) agriculture. Silt, clay and fine sands eroded from this area are carried in suspension to the coast.. Rolling and undulating areas show little erosion of the brown clay soils of low natural fertility found there. When farming occurs on this soil, however, clays descend in the soil profile causing drainage and root aeration problems (Heyman *et al. 1995).*

The coastal flatlands are a mixture of landscape types including freshwater swamps with clay and silt soils, old and new coastal sand deposits with sand and loam soils, and intertidal mangroves with saline peaty soils. Mangroves act to filter some fluvial erosional products and catch large vO~}lmesof organics from litterfall. Agricultural use of this area is minimal due to fertility and drainage problems (Heyman *et al.* 1995).

At 16°25" N latitude the climate of the area is moist subtropical receiving nearly 4 meters of rain annually. Rainfall patterns show clear seasonality with a rainy season starting in May/June peaking in July/August and tapering to the dry season which is most intense from February through April.. Mean yearly temperature of the area is approximately 25° C (78° F) with a maximum mean temperature from June to December of 26.5° C and a minimum from December to February of 22° C. Relative humidity ranges between 40 and 99 %, with a mean of about 80%. Easterly tradewinds blow consistently throughout most of the year with heavy storms and winds coming from the north

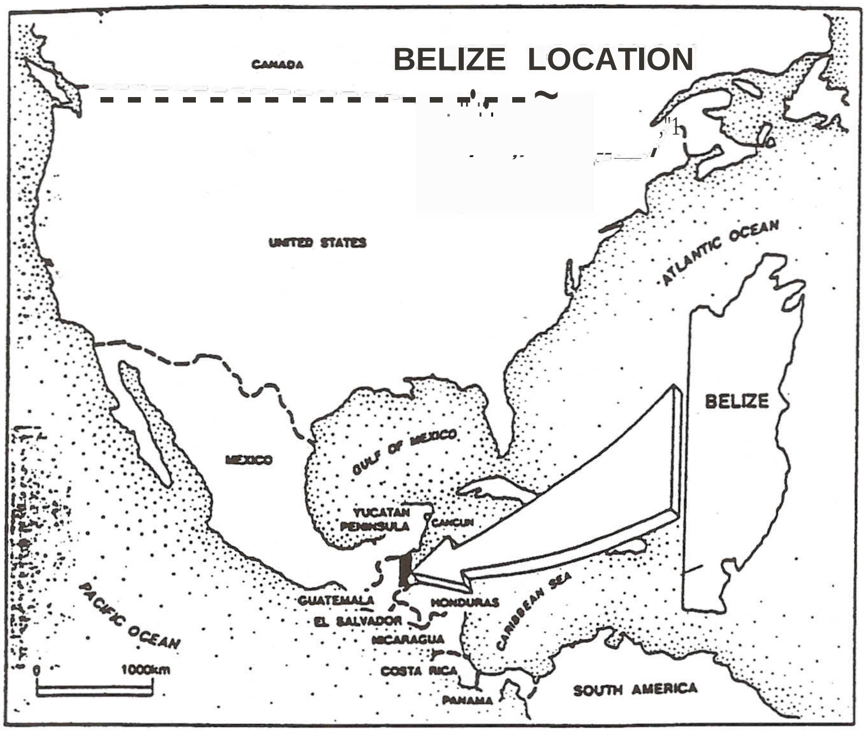

Figure 1.1: Belize Locator Map

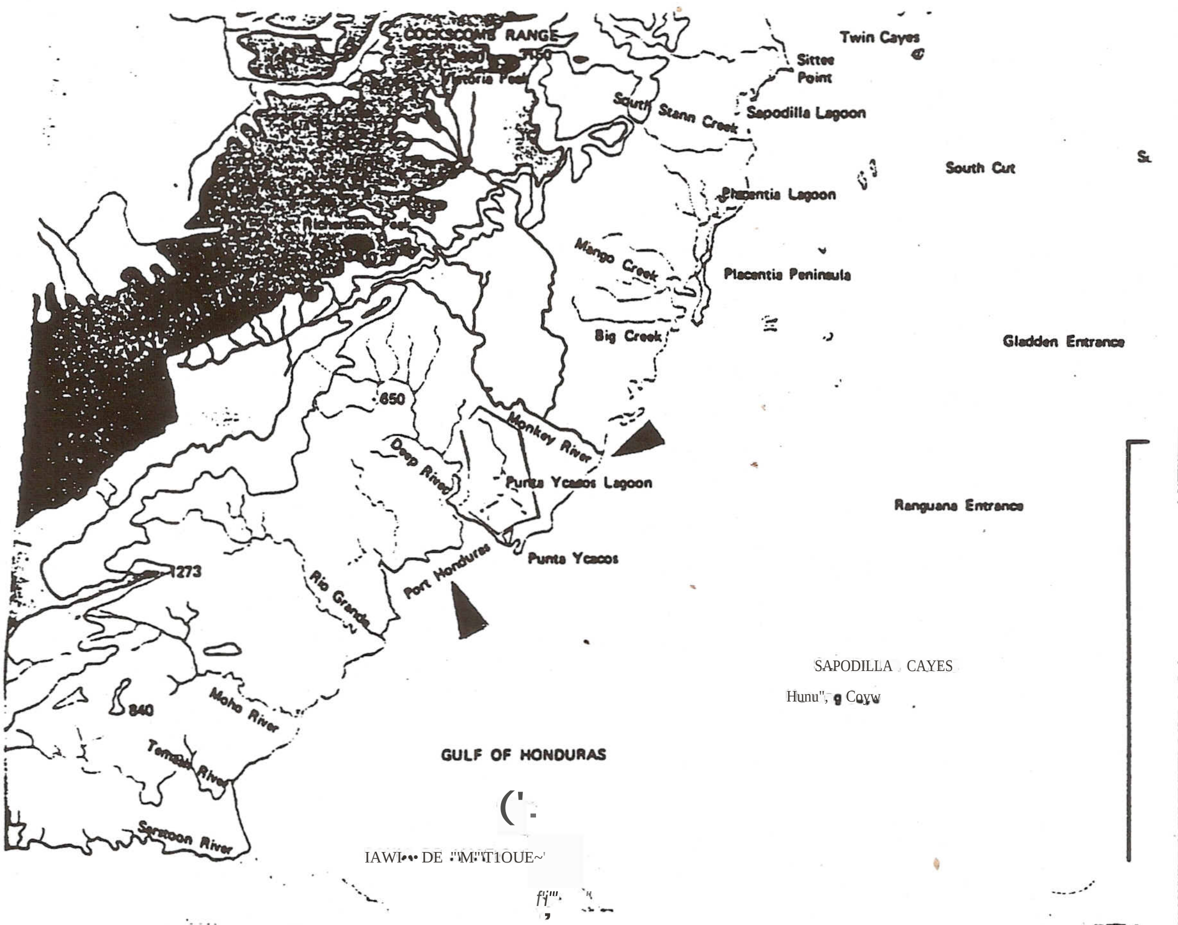

Figure 1.2: Southern Belize: Monkey RiverlPort Honduras Area

in the winter months. Hurricane season is from August to October though the Toledo district is rarely impacted because of the shelter provided by the bight of Honduras.

As discussed above, the Bladen Branch of the Monkey River drains quartz rich igneous slopes and flows through karstic limestone and undulating hills (where it meets the Trio Branch) before meeting the Swasey Branch in the coastal flatland area. The contrast of seasonal flows is dramatic. During the dry season portions of the Bladen Branch flow underground whereas during flooding the river can rise twenty feet above dry season banks (Heyman *et al.* 1995). The upper portion of the branch supports twelve vegetation types and much endemic fauna (lyre and Sangermonger 1996, Arrigoni 1995) and is almost entirely protected by the Bladen Nature Reserve which is currently unmanaged although management planning is now underway. Agriculture is absent in this sub-basin above the Trio Branch confluence with some banana and citrus cultivation nearer the Swasey confluence (Perry 1995).

The Swasey Branch of the Monkey River drains the Cockscomb Basin (in part protected as the Cockscomb Basin Jaguar Preserve), and flows through Maya Mountain Forest Reserve which is also drained by the Trio Branch. The lower reaches of these branches flow into the undulating and rolling areas that have been deemed suitable for agriculture. Large-scale commercial banana production is taking place in these areas for export to European markets. There is also smaller scale mango, citrus, and milpa agriculture taking place here and a new tilapia fish farming facility. Cowpen Village, a migrant community, is located in the banana growing region of the Swasey Branch along with multiple smaller settlements.

The Bladen and Swasey Branches join as the Monkey River six miles from the sea. The entire lower reach of the river from the confluence is protected as the Monkey River Special Development Area which includes Monkey River Village, a small fishing community at the river mouth.

The Monkey River drains into the Caribbean Sea just north of the Port of Honduras, a coastal area that is "loosely defined as the area of sea between Rio Grande and Punta Ycacos on the coast, and includes the Snake Cayes as an outer boundary" (Fig. 1.3; Heyman *et al.* 1995). At times of high flow the Monkey River has a sediment plume extending up to 12 miles into the sea to the east and south, having a definite impact on the Port Honduras area. Port Honduras can be broken into functional ecological units as (1) the coastal intertidal mangroves, (2) the lagoon waters including the inner cayes, and (3) the offshore banks including the Snake Cay~s(Hey man *et al. 1995).*

Port Honduras is rimmed with extensive red mangrove *(Rhizophora mangle)* forest followed by buttonwood *(Conocarpus erectus),* white *(Laguncularia racemosa),* and black *(Avicennia germinans)* mangroves on higher ground. Large coastal ponds are connected to the sea via rivers and contain extensive mangrove habitat.. The mangroves act as energy buffers for catastrophic storms, as filters for upstream erosional products, and as the primary source of organic matter "for higher order coastal productivity and thus support a great diversity and abundance of commercial and sport fish species" (Heyman *et al. 1995).*

More than 130 mangrove cayes exist in Port Honduras, providing protection from easterly winds and causing a gradation from estuarine to fully marine habitats. The volume of sands found on the cayes is highest on cayes to the north and east where sand from the Monkey River settles out of suspension. Benthic environments within the lagoon area are dominated by mud bottom habitat,

SETTLEMENTS IN TOLEDO IN RELATIONSHIP TO PROTECTED AREAS

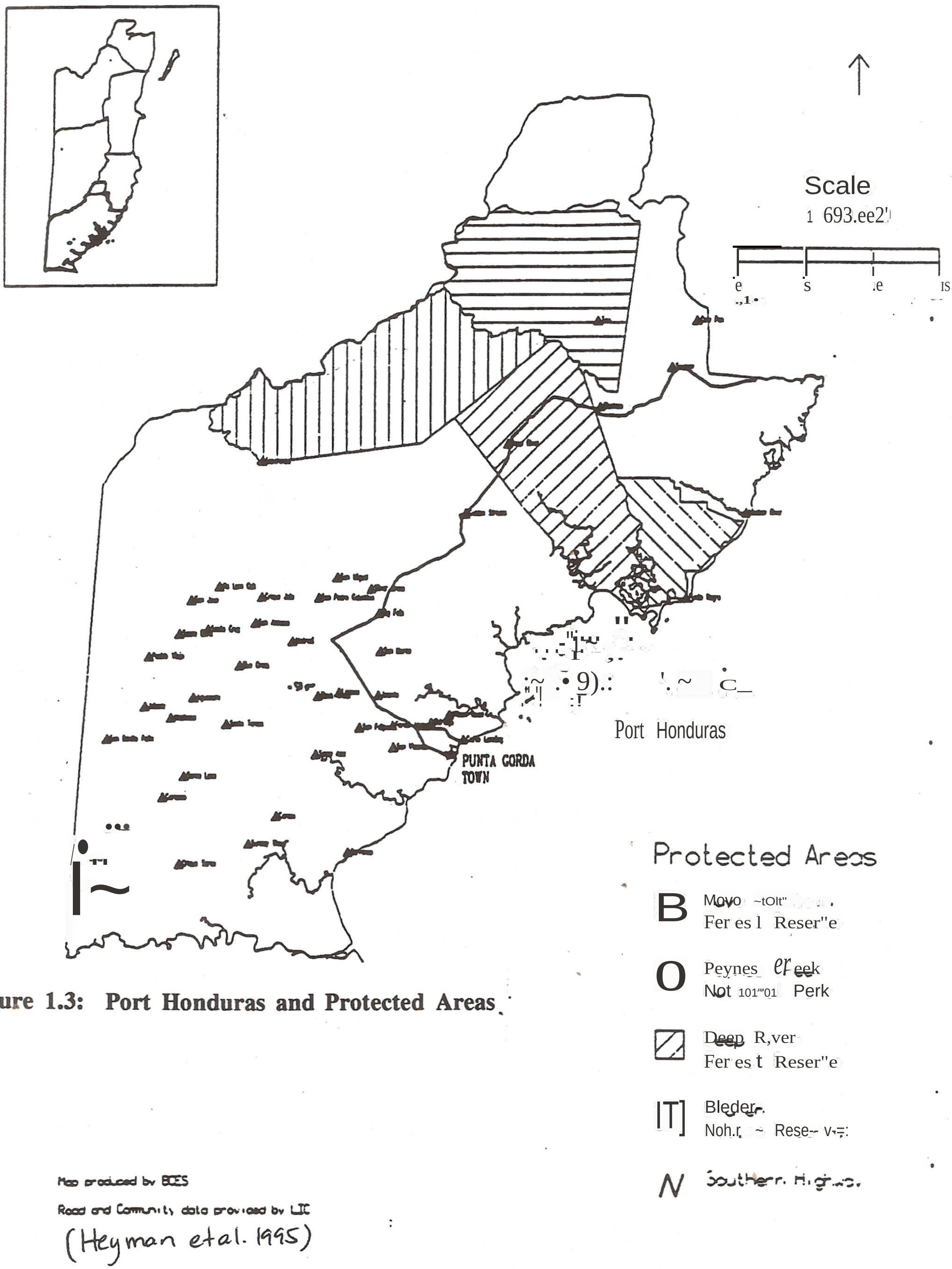

Figure 1.3: Port Honduras and Protected Areas

seagrass beds, and coral flats existing in less than two meters of water. The Snake Cayes on the outside edge of Port Honduras have sandy beaches, mangroves, and some upland vegetation (Heyman *et al. 1995).*

Faunal diversity in the Port Honduras area is rich with numerous species of coral, fish, birds, reptiles, and marine mammals. Notable species include the West Indian Manatee *(Trichechus manatus),* several species of dolphin, American crocodiles *(Crocodylus acutus),* hawksbill sea turtles *(Eretmochyles imbicata),* loggerhead sea turtles *(Caretta caretta),* green sea turtles *(Chelonia mydas),* spiny lobster *(Panularis argus),* conch *(Strombus gigas),* and jewfish *(Epiniphelus itajara)* (Heyman *et al. 1995).*

1.2 Ecosystem Functions: Linkages Between Aquatic, Terrestrial, and Marine Areas

The purpose of this section is to provide a conceptual ecological basis with which to examine impacts of land use activities in the Monkey River drainage area. Of particular importance to watershed ecology in the Monkey River catchment are linkages between terrestrial ecosystems and aquatic ones, and between the terrestrial/aquatic nexus and the coastal zone ecosystem. Resource use in the watershed has initiated a domino effect where terrestrial development activities are effecting the aquatic ecosystem which in turn influences the coastal zone. As Gregory *et al.* (1991) comments:

> More than any other ecosystem, the structure and processes of lotic ecosystems are determined by their interface with adjacent ecosystems. Thus the necessity for an ecosystem perspective of aquatic and riparian ecosystems-viewing either ecosystem in isolation gives an ecologically incomplete view.

Likewise, marine ecosystems must be viewed with lotic systems for a complete picture. Coastal and marine areas are the sink for riverborne sediments, nutrients, and pollutants originating upstream in the Monkey River drainage basin.

Aquatic - Terrestrial Linkages: The Importance of Riparian Forests

Gregory *et al.* (1991) define riparian zones as "three dimensional zones of direct interaction between terrestrial and aquatic ecosystems. Boundaries of riparian zones extend outward to the limits of flooding and upward into the canopy of streamside vegetation." Geomorphologyand natural disturbances (including fluvial and non-fluvial disturbapces) are identified as major influences on the high degree of structural andcompositional diversity found in riparian forests. Riparian zones function as corridors for movement of both planls and animals. They also act a refugia for plants, harboring both species associated with hydric soils and those associated with drier upland soils (Kellman and Meave 1994).

Riparian forests and streams interact in a number of ways. The forests influence channel geomorphology through (1) reducing erosion through rooting the soil; (2) increasing channel roughness during overbank flow (reducing erosion and retaining material in transport); and (3) by adding large woody debris to channels, changing flow dynamics and creating habitat.. Other "interactions between terrestrial and aquatic ecosystems include modification of micro climate (e.g., light, temperature, and humidity), alteration of nutrient inputs from hillslopes, contribution of organic matter to streams and floodplains, and retention of inputs" (Gregory *et at.* 1991). The forests influence the aquatic trophic structure heavily, providing detrital matter for aquatic invertebrates and modifying primary production in the stream through shading. Forests thus indirectly affect aquatic and non-aquatic vertebrates that rely on invertebrates for prey and use the forests as habitat..

Riparian forests play a significant role in the interception of nutrient loads from agricultural land. Studies of nitrate and phosphorous interception in temperate ecosystems have shown riparian forests to be responsible for removal of more than three-quarters of the dissolved nitrate transported from croplands and thirty percent of the phosphorous contributed in soil solution (Peterjohn and Correll 1984, Lowrance et al. 1984). Thus the removal of riparian zones between agricultural land and streams will allow nutrient loads into the lotic system unimpeded.

Vannote *et. al.* (1980) represent the entire watershed as a continuum defining it thus:

> From headwaters to mouth, the physical variables within a river system present a continuous gradient of physical conditions [which] should elicit a series of responses within the constituent populations resulting in a continuum of biotic adjustments and consistent patterns of loading, transport, utilization and storage of organic matter along the length of a river.

Indeed, removal of riparian forests elicits a series of responses within the aquatic ecosystem. Physical responses include increased sediment and nutrient transport, increased amount of direct sunlight, and reduced contribution of leaf litter to the energy flow. Each of these factors in turn influences biotic factors.

Sediment and Nutrient Transport

> Streamside vegetation reduces both sediment and nutrient transport, which tend to be related because substantial nutrient loss from agricultural watersheds occurs in association with sediments (Allan and Flecker 1993).

By removing streamside vegetation, interception of rain by foliage ceases and the stabilizing root mass and ground cover of fallen plant material are removed. Tree stems that add to channel roughness during overbank flow also disappear. Increased sediment in the river results, having a number of impacts on aquatic ecosystems and the organisms that rely upon them. Aquatic organisms are particularly susceptible to impact as they are usually confined to the stream channel and cannot avoid environmental threats.

Sediment in streams can be suspended (particles in the water column), deposited (particles on the stream bed) or hyporheic (particles in the matrix of the stream bottom). Suspended sediments "should be viewed like other toxicants where exposure time and concentration together determine the effect on aquatic communities" (Metzeling *et al.* 1995). The effects of low levels of sediment over a long period of time have been showed to be similar to high levels of sediment over a shorter period of time.

Much aquatic and non-aquatic biota are effected by sedimentation. Studies of the impacts of suspended sediment on fish have evidenced direct fatality, reduced growth rates, reduced feeding, altered diet, increased stress, increased incidence of disease, altered behavior and displacement. . Other effects include a reduction in oxygen uptake from the coating or clogging of gills, and reduction in feeding efficiency for visual predators. Deposited sediment also affects fish by reducing usable habitat areas for feeding, spawning, egg laying, and hatching. Freshwater flora may be affected by sediment in a number of ways including smothering by deposited sediment and reduction of light levels. Suspended sediments effect aquatic macroinvertebrates in similar ways to fish (mortality, reduced oxygen uptake, behavioral changes). Smothering by deposited sediments reduces habitat diversity, covers food sources for grazers, and may disturbed decomposition and feeding on detritus. Hyporheic sedimentation can affect refuge availability for invertebrates during time of stress. Many birds, reptiles, and amphibians, and some mammals, though they live outside aquatic systems, rely heavily on aquatic food resources. Thus as these food resources are impacted by sedimentation, so are non-aquatic organisms in higher trophic levels (Metzeling *et al. 1995).*

Suspended sediment also effects the temperature of river waters. Increased suspended solids in the water column make the water more turbid, causing greater sunlight absorbtion and increased water temperatures (Mitchell and Stapp 1993). The effects of increased water temperature are discussed in detail below.

Stream form also changes with increased sediment load. Streams are always changing and adjusting gradient, sediment load, mean sediment size, and discharge in order to achieve a balance between erosion and deposition (Chemicoff 1995). Increased sediment load will thus cause changes in all of these factors, accelerating the change of river's course and overall stream gradient..

Increased nutrient transport to the stream channel can have numerous effects. Sources of nutrients in runoff are natural soilleachates and additives from agriculture including phosphorous and nitrates. Unattached inorganic phosphate in water is a "growth limiting factor" as it is necessary for plant growth and usually found in quite low concentration. "Even a small increase in phosphorous can cause a large increase in the growth of aquatic vegetation like algae and submerged plants" (Behar 1996). Nitrogen is another nutrient that encourages plant growth. The process of increased plant growth from anthropogenic nutrients in a river is called *cultural eutrophication.* Cultural eutrophication can cause lowered levels of dissolved oxygen in the river altering biological processes such as respiration, decomposition, and chemical and nutrient conversion (Behar 1996).

Temperature Change and Direct Sunlight

Shading by riparian forest canopy ameliorates temperature extreme, resulting in lower maximal values in summer and higher minimal values in winter (Allan and Flecker 1993).

Based on the River Continuum Concept of Vannote *et al.* (1980) the removal of the shade-providing forests along a stream will cause biotic adjustments throughout the ecosystem. Increased solar exposure raises river temperatures and increases the photosynthetic zone allowing increased primary production of algae and river plants. Increased water temperature has multiple influences on the river system including:

(1) the lowering of dissolved oxygen content in the water ("cool water can hold more oxygen than warm water, because gases are more easily dissolved in cool water" (Stapp and Mitchell 1995));

(2) an increase in the rate of photosynthesis of algae and larger aquatic plants, accelerating produc-

tion of dead plant material which increases aerobic digestion and further intensifies oxygen demand;

(3) an acceleration of the metabolic rates of aquatic organisms, again increasing oxygen demand and altering life cycles;

(4) a change in species assemblages towards warm water adapted organism; and

(5) an increase in organism sensitivity to toxic wastes, parasites, and diseases from the stresses of increased water temperature and lowered dissolved oxygen availability;

Altered Nutrient Exchange

The forests feed the rivers and the rivers feed the sea (Boles 1994).

"Riparian plant communities offer an abundant and diverse array of food resources for both aquatic and terrestrial consumers. Much of the food base for stream ecosystems is derived from adjacent terrestrial ecosystems" (Gregory *et al.* 1991). In a New Hampshire stream study, 98% of the organic matter in the stream was supplied by the surrounding forest (Fisher and Likens 1973). In addition to providing raw energy to aquatic biota in the form of organic matter, streamside vegetation also contributes to habitat diversity in streams through shading, treefall, and detritus beds. Removal of this source of energy and habitat variability reduces biotic productivity and changes species assemblages .

Linkages Between the Terrestrial/Aquatic Nexus and Port Honduras

> ...The value of Port Honduras is as a habitat linkage between watersheds and the sea, in which the mangrove and seagrass habitats along the coast and in the cayes contribute greatly to coastal and offshore fisheries production (Heyman *et al. 1995).*

Rivers support productivity of both mangroves and sea grass beds-plant communities that have been deemed the greatest contributors to primary production in tropical coastal areas (Lewis 1977). In Port Honduras, red mangrove *(Rhizophora mangle)* and turtle grass *(Thalasia testundinum)* are the key primary producers to offshore fisheries production (Heyman *et al. 1995).*

Increased flow in drainage basins mobilizes increased terrestriai nutrients (adsorbed to suspended soil particles) that are released in the mangrove estuary (Kjerfve 1990). Such nutrient loading and freshwater turnover in mangroves is predicted to lead to highest productivity (Day *et al.* 1987). High mangrove productivity in turn relates to high fisheries production. Numerous studies correlate the extent of estuarine wetlands (usually mangro.ves) and fisheries production in nearby coastal waters (Marosubroto and Naamin 1977, Turner 1977, Turner 1992). Stomach contents of commercially valuable fish species in Florida found 80% of the sample to have mangrove detritus in the gut (Odum 1970). "In sum, the rate of mangrove primary production, the aerial extent of mangrove habitat, and the volume of freshwater input are all determinants of the value of an estuarine habitat for fisheries production" (Heyman *et al. 1995).*

Seagrass beds are important for epiphytic colonization, herbivore grazing, and as contributors to the detrital food loop (Fig. 1.4). "By contributing to the detrital food loop ...seagrasses provide

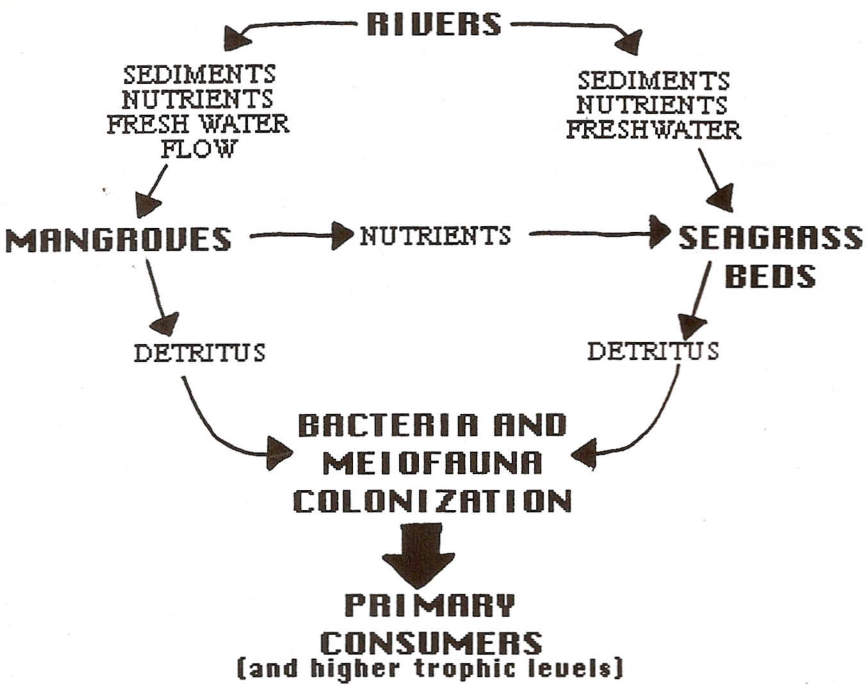

Figure 1.4: Detrital Food Loop

nutrients for higher order productivity, and ultimately fisheries" (Heyman *et al.* 1995). Productivity of seagrass beds is affected by salinity, temperature, and substrate type. Turtle grass derives the bulk of its nutrients from sediments in which it grows (Zieman 1975). In part, these benthic sediments are deposited by rivers that deposit their suspended load upon entering the coastal area. Excessive sediment depresses seagrass productivity as plant leaves get buried and access to light for photosynthesis is limited. (Heyman *et al.* 1995).

Both mangrove forests and seagrass beds contribute organic matter to the detrital food loop. In the detrital food loop, fallen leaf litter from mangroves or seagrass beds is colonized by fungi and bacteria followed by colonization by meiofauna and zooplankton which graze on the decomposers. The decomposing detritus becomes enriched by protein from decomposers giving the material a higher nutritional value. Over time the plant material is broken into smaller and smaller pieces that are eaten by detritivores. Particles that are stripped of the protein-rich microbial coating restart the decomposition process with recolonization by fungus and bacteria. In this way, all of the original leaf material is used up over time. The detrital food loop, "serves as a vital link between inedible primary production from mangroves and seagrasses, and higher order consumers, such as shrimp and fish" (Heyman *et al.* 1995).

As discussed above, an increase of nutrient availability can cause cultural eutrophication in aquatic and marine environments. Though the nutrient increase may benefit mangroves, eutrophication can have deleterious effects on coral communities. Hunte and Wittenberg (1992) found that "the abundance of juvenile corals was lower on eutrophic reefs than on less eutrophic reefs in Barbados and that one cause of this was higher juvenile mortality on eutrophic reefs." They also found that coral settlement rate decreases on more eutrophic reefs. These results could be from lower local availability of larvae or from lower probability that larvae will settle when present (possibly due to lack of suitable substrate). Damage to the coral reef has multiple implications for both fisheries production, trophic structure, and tourism in the Port Honduras area.

> It sh9Uld be clear that the physical and biotic components of the ecosystems connecting the ridge of the Maya Mountains to the Southern Barrier Reef are intimately linked ...[thus] alteration of upland areas must proceed with great caution, especially in areas with higWy erodible soils, and/or near water courses that drain to Port Honduras. It should be clear that alteration of upland habitat can cause increased erosion, which can drastically reduce the contribution of primary producers to fisheries. Since Port Honduras is such a critical fisheries habitat, this resource must be protected both directly, with strict enforcement of fisheries laws, and indirectly by protecting relevant ecosystem processes that support the fish populations (Heyman *et al. 1995).*

1.3 Resource Use in the Monkey River Watershed

The Monkey River watershed has attracted commercial and non-commercial land uses and numerous human settlements. By far the most important land use activity (as an economic base and source of river stress) is large-scale commercial banana production. Other notable land-uses in the drainage include tilapia *(Oreochromis mossambicus)* aquaculture and some milpa agriculture. As discussed in the previous section, marine fisheries production is directly impacted by upstream watershed activities. This section will examine these development activities more closely.

<u>Banana Production</u>

Bananas are one of Belize's principal export crops accounting for 10.5 percent of total export earnings. All banana exports are destined for Europe-approximately 40,000 tons per annum to be increased in the near future to 55,000 tons. The industry is known for its use of multiple pesticides for the control of pests and diseases that cause economic losses to the crops. The most damaging are fungal diseases to bananas including the black sigatoka disease. Fertilizers are also heavily applied throughout banana producing areas including iarge amounts of macronutrients and lime. The environmental impacts of these pesticide and fertilizer applications are significant given the proximity of banana growing areas to river systems.

Fifty-two percent of banana production in Belize is located on tpe Swasey Branch of the Monkey River with a total of 2,449 acres in cultivation (Usher and Pulver 1995). Together with cultivation on the Trio Branch and banana cultivation on the lower Bladen Branch, the Monkey River watershed accounts for 76% of land cultivated for bananas i? Belize (Heyman *et al. 1995).*

~Pesticide and fertilizer applications to bananas include two herbicides, four foliar applied fungicides, two insecticides and/or nematicides, two fertilizer formulations, and one soil amendment (Usher and Pulver 1995).

The two herbicides used are paraquat and glyphosate. Paraquat use in the entire industry in Belize is estimated to be 1.1 tons per year over 1964 ha. About 500 kgs of glyphosate are also applied annually. Both of these herbicides have no residual herbicide activity as they are both strongly adsorbed to soil particles "rendering them biologically inactive." Neither product is known to be toxic to fish or bioconcentrated (Usher and Pulver 1995).

One hundred tons of four foliar applied fungicides were applied over the entire banana area in 1994. Half of this was applied to bananas grown in the Swasey River sub-catchment. . All of the foliar fungicides applied adsorbed to soils in varying degrees. Tridemorph is very strongly adsorbed, moving only with sediment flow. Mancozeb is strongly adsorbed, but does move in solution due to the quantities with which it is applied, and propiconazole is intermediately adsorbed to sediment (Usher and Pulver 1995).

Over 50% of the two insecticides (terbufos and ethoprophos) being used in banana cultivation in Belize is applied in Swasey River watershed with 37 tons being applied annually over the entire banana growing area in Belize. Terbufos is highly volatile and readily adsorbed to soil particles and only slightly soluble in water. Ethoprophos is not adsorbed to soil and is highly water soluble moving readily by leaching (Usher and Pulver 1995).

Large amounts of fertilizer are used throughout the banana industry including 809 tons of nitrogen, 256 tons of phosphorous, and 1,413 tons of potassium in 1994. Additionally, 1,760 tons of burned lime were applied. "The large amount of nutrients ...entering the water sources yearly must be causing eutrophication in the rivers and coastal areas" (Usher and Pulver 1995).

The two products suspected to be accumulating in the environment are mancozeb and ethoprophos. For mancozeb, 31.9 tons accumulate annually after the fifth year of use. "This is an extremely large amount of pesticide in the environment. . Caution should be exercised in using the waters draining the banana producing areas, especially the Swasey River" (Usher and Pulver 1995). Ethoprophos accumulates at a rate of 1.87 tons per year and is readily found in the water system and has already entered coastal areas.

According to Heyman *et al.* (1995), "Banana cultivators have shown little respect for legislation protecting riparian areas or human health as aerial spraying continues over fields in which people live." Perry (1995) estimates that more than six kilometers of riparian habitat have been destroyed on the Bladen Branch and more'than 24 kilometers on the Swazey Branch, with plantations extending directly to the river banks. "The river banks were being stripped away ferociously leaving four meter high walls of soil" (Perry 1995). Perry also comments that banana trees could be seen toppling directly into the river as banks were eroded away and that benthic habitat was "choked" with silt.

As discussed in Section 1.2, riparian forests play essential roles in protecting streams from bank erosion, nutrient, and soil runoff and in moderating river temperatures, providing nutrients, and habitat.. Compliance with riparian clearing laws, restoration of streamside vegetation, and better soil management practices will all act to ameliorate impacts from sediment and nutrient runoff into the stream.

Tilapia Farming

Farming of Mozambique tilapia *(Oreochromis mossambicus)* is now occuring on the lower Swasey Branch of the Monkey River below Logan's Bank. The facility consists bf multiple two acre ponds each containing approximately 35,000 individual fish. Tilapia is known for its rapid life cycle, its efficiency as an herbivore, and its desirability as a food source. Aquatic ecologists know tilapia more as an invasive exotic species. "Mozambique tilapia is now established in nearly every tropical and subtropical country" (Bright 1995). With this in mind, wholly native aquatic systems should be viewed as threatened ecosystems and protected as such.

Negative effects of established exotic species on native biodiversity can be many including predation, habitat alterations, hybridization, and introductions of diseases or parasites (Taylor *et al.* 1984). Once exotic species are established they usually are impossible to eradicate (Allan and Flecker 1993). Tilapia have already established populations in the Crooked Tree Wildlife Sanctuary in northern Belize, most likely introduced accidentally from nearby fish farms(Boles, pers. comm.). Despite protection measures taken by the industry, there is no guarantee of zero escape. The isolated release of one gravid female could potentially alter the lotic system indefinitely. Wading birds should be seen as a potential vehicle for the spread of this exotic (Boles, pers. comm.). Establishment of tilapia into the Monkey River would alter the stream irreversibly. In the words of Noss and Cooperrider (1994), "No exotics (introductions or transplants) should be introduced into any waters and existing nonnative species should be eliminated."

Beside being a risk to native species, aquaculture also contributes pollutants to streams. Periodic flushing of pond water releases accumulated metabolic byproducts and nutrient loaded water from fertilizers and feed. Both of these pollutants can lead to eutrophication and decreased dissolved oxygen in the stream water (Alegria 1993).

Fisheries

Both commercial and sport fishing occurs within the Monkey RiverlPort Honduras area supporting nearly 500 Belizeans from southern coastal areas. The most important fisheries product in the Port Honduras area, accounting for 67% of local income from fishing, is spiny lobster *(Panularis argus)* which contributes a minimum of BZ$950,OOO per year to the area. The legal catch from Port Honduras accounts for 10% of the national lobster export for the country of Belize. After lobster, the most valuable fisheries product in the Port Honduras area are pelagics (such as barracudas, jacks, and mackerel) followed by snappers (lane, mutton, red, yellowtail), accounting respectively for 15% and 8.1% of local yearly income (Heyman *et al. 1995).*

Fishermen surveys in the Port Honduras area indicate an overall decline in numerous commercially valuable species including conch, snook, lobster, shrimp, and snappers. They attribute this decline to use of nets, overfishing, and fishing by illegal aliens from Guatemala and Honduras. They also commented on the hunting of manatee for meat by these same alien fishermen.

With declining populations of commercially valuable fisheries, sport fishing is being proposed as a potentially lucrative and sustainable income for local fishermen. Four sport fish occur in and about the Port Honduras area including bonefish *(Albula vulpes),* permit *(Trachinotus falcatus),* snook *(Centropomus undecimalis),* and tarpon *(Megalops atlanticus).* Fifty-six percent of fishermen in the Port Honduras area have done sport fish guiding, and want to do more-and with good reason. Sport fish guides make an average of BZ$31 per hour compared to the BZ$ll per hour made by commercial fishermen. A tarpon caught and sold by a commercial fishermen will bring in approximately $30 per fish compared to an income of BZ$400 per day guiding tourists to catch and release the same tarpon. Along with guiding fees come secondary income made from lodging, meals, crafts, and other local products. "Sport fish guiding is more lucrative, and less work than commercial fishing, with far less damage to the environment" (Heyman *et al. 1995).*

Tourism

Along with tourism initiatives like sport fish guiding, the potential for ecotourism in the Monkey RiverlPort Honduras area is high. Ecotourism as defined by Palacio (1992) is "A form of tourism inspired primarily by the natural history of an area, including its indigenous cultures. The ecotourist visits relatively undeveloped areas in the spirit of appreciation, participation, and sensitivity. The ecotourist practices a non-consumptive use of wildlife and natural resources and contributes to the visited area ...directly benefiting the conservation of the site and the economic well-being of the local residents." Much ecotourism occurs in conjunction with or in proximity to protected areas and parks. A full 63% of tourists in Belize visit a park or protected area during their visit (Boo 1990). With five protected areas in the Monkey River catchment alone, not to mention numerous others in neighboring watersheds, the potential for use of the area for ecotourism seems high. Some deterrents to ecotourism might include the remoteness of the area and the proximity of communities to banana plantations.

Surveys of communities within the Maya Mountain Marine Area Transect by Heyman et al. (1995) showed varying support for tourism and protected areas. The responses can be clearly correlated to one variable-whether or not the communities were already receiving tourism. Communities that were already receiving tourism answered strongly positive to wanting more tourists in their villages and in support of protected areas. Communities that are potential tourist destinations but have not yet received tourists, were far less certain of tourism and protected areas, with the majority undecided in each case. Well-funded outsiders starting ecotourism businesses threaten the viability of ecotourism in both current and potential destination communities.

1.4 Socioeconomic Profiles of Monkey River Watershed Communities

According to the Belize Ministry of Tourism and Environment (1994), Belize ranked 67th among all nations on the Human Development Index in 1993. Per capita Gross Domestic Product for that same year was BZ$4,447 (CSO, 1994). Life expectancy in the country is 69.5 years and about three quarters of the population has access to clean drinking water and health services. The population of Belize in 1993 was officially 205,000 (CSO 1994) over a land area approximately the size of the state of Massachusetts.

A statistical profile of the Monkey River watershed would undoubtedly show far less favorable results. Dominated by banana production, much of the population within the drainage consists of migrant workers from Guatemala and Honduras with one n?table standout, Monkey River Village on the coast.. "While the banana industry serves as a major employer for the district, economic and social conditions for employees are less than adequate" (Heyman *et al.* 1995). This summary may itself be an understatement. . Vix (1996) provides a detailed description of housing conditions in Cowpen Village:

> Dwellings of mud and deteriorating thatch line the banana fields, home to many of the workers' families. Pools of urine sit on kitchen floors, unable to permeate into the ground. Plastic tarps hang from the ceiling to prevent complete leakage from the aerial chemical spraying. Well water is contaminated by the runoff from the fields, fertilizers and insecticides, and human waste. The water, stagnant and dark brown, inevitably causes many ill-

nesses. The workers who live on the plantations are now being ordered to leave their homes, yet are not receiving any compensation for even the materials, making it very difficult to afford other housing.

Barry (1991 in Vix 1996) reports the "lack of health and sanitation facilities, substandard housing, careless aerial spraying and polluted drinking supplies," and a 1994 paper by the Belize Center for Environmental S~udies and the University College of Belize calls immigrant labor "a community with no political voice, controlled by the large banana farms ...similar to the plantation economy seen in the southern US in the late 18th century." Wages for banana workers are the Belize minimum BZ$2.00 per hour for agricultural work.

In response to the abysmal living conditions and low wages, some banana workers formed the United Belize Banana Workers Union (also known as Banderas Unidas) in May, 1995. On 12 June 1995, six hundred union members from three farms went on strike. The Banana Growers Association representing private capital, responded by deporting 125 immigrant workers, replacing 400 more, and canceling 200 work permits (*Amandala,* 30 June 1995).

Communities in the Monkey River watershed serving the banana industry include Trio Village, Cowpen Village, Swasey Village, Bladen Village, San Juan Bosco, and Bella Vista. Population statistics for these villages are largely unavailable due to the transient nature of the communities, but figures likely exceed 3000 residents at any given time. Bladen Village is inhabited largely by Maya who have settled along the highway. The remaining villages are migrant communities: Besides working for regional banana farms, many of the families in these villages supplement their food supplies with milpa agriculture, fishing from the Monkey River, and hunting in areas such as the Bladen Nature Reserve.

Monkey River Village differs tremendously from the migrant banana worker settlements upstream. Located along the sandy beach south of the mouth of the river, the inhabitants of the village are Belize Creoles. Once a thriving town of several thousand people prospering from banana cultivation in the watershed, Monkey River has declined to a population of approximately 200 people surviving almost exclusively from fishing the Port Honduras waters. There are some subsistence agricultural activities around Monkey River Village including the harvest of plantain, corn, cassava, and other root crops. The village formed the Monkey River Special Development Area (SDA) in 1993 to generate economic income through tourism and agriculture. The SDA protects land on either side of the river up to the confluence of the Bladen and Swasey Branches. Coastal tourism for fishing snorkeling and jungle walks is spreading to Monkey River Villages and promises to continue in the future supplementing income from the declining fishing industry .

In developing conservation management strategies for the MMMAT and the Monkey River, care must be given to avoid unintentional discrimination against immigrant communities based on their perceived illegitimacy in the Belize social context, language barriers, or difficulty accessing these communities. As a proportion of residents in the Monkey River watershed and entire MMMAT, immigrant laborers clearly constitute the majority and undoubtedly impact the landscape as such. Due to the transient nature of migrant communities and pressures on laborers to avoid "subversive activities", research and relationship building in these communities by "outsiders" will be difficult.. According to Palacio (1990), 60 percent of refugees and economic immigrants plan to stay in Belize. With this in mind, building a partnership with Banderas Unidas may well be a way to access this 60 percent to coordinate sustainable conservation activities. In conjunction with river monitoring activities, well-water and human health assessments are critical for building a comprehensive information base documenting impacts of the banana industry in the Monkey River watershed.

1.5 Regional Conservation Planning and Management Initiatives

Belize has great potential to become an example of successful integration of development and conservation activities. With 35 percent of the country's land area in protected status; comprehensive environmental protection and natural resource use legislation; and multiple land-management initiatives, conservation is certainly on the national agenda.

National Legislative Framework

Belize Environmental Protection Act

The Belize Environmental Protection Act (entered into force on 6 January 1993) "is an Act relating to the preservation, protection and improvement of the environment, the rational use of natural resources, the control of pollution, and related or incidental matters. The primary focus however, is the regulation of pollution" (McCalla 1995). The Act established a Department of the Environment within the Ministry of Tourism and the Environment responsible for administering and enforcing the Act and "regulations made thereunder".

Section 10 (1) of the Environmental Protection Act (EPA) requires that any person "exploiting natural resources (e.g., forests) is required to ensure the protection of the environment against unnecessary damage by pollution or harmful substances" (McCalla 1995). Section 10 (2) requires that resource exploiters shall ensure that "chemicals and biologicals" introduced into the soil through development activities will not contaminate the soil, water, or biological entities such that the ecosystem is disturbed. The Act also prohibits waste discharge that might directly or indirectly pollute water or marine resources. Furthermore, an Environmental Impact Assessment (EIA) is required from any person undertaking a major development project "which may significantly affect the environment" .

Section ten of the EPA is clearly important to support a comlllUnity level effort to protect shared natural resources such as a river. Usher and Pulver (1995) have reported on the accumulation of pesticides and chemical runoff into the Swasey Branch of the Monkey River. Clearly banana developers are already in violation of the EPA. This Act may p'rovide the basis for future legal action should tilapia ("biologicals")' escape the aquaculture facility in the lower Swasey Branch and establish populations in the ecosystem.

Land Utilization Act

Under section 19 of the Land Utilization Act, special development areas (SDAs) are defined including the Monkey River SDA.. The Monkey River SDA is declared (in S.I. 152 of 1991) to facilitate "the economic generation of the area through a mix of locally controlled tourism and agriculture" (McCalla 1995). The presence of this SDA is a plus for the development of a river monitoring program as it could be argued that impacts to the river (direct and indirect effects on wildlife, impacts on reef) effect the ability of the SDA to fulfill its function of facilitating tourism. Through the existence of the SDA, Monkey River Village community members also have been introduced to ideas of sustainable development and conservation.

The Land Utilization Act (Cap. 185 A) empowers the Minister of Natural Resources "to make regulations for the better use of land, having regard to the fact that improper land use may bring about floods and erosion" (McCalla 1995). These regulations relate to the demarcation and protection of watersheds and the protection of riparian areas to prevent soil erosion. The National Lands Act of 1992 mandates a riparian buffer zone of 66 feet along any running streams river or open water outside of towns and villages. Activities to be carried out inside this riparian buffer must meet with the approval of the Minister. This is a key piece of legislation for making a case for restoration efforts in the watershed. The 66 foot mandate is known to have been violated in multiple instances on all branches of the Monkey River. Bringing the industry and the Banana Control Board to comply with this mandate in the future will be essential to halting further degradation of the terrestrial and aquatic ecosystems in the watershed.

Common Law Controls Over Fresh Water

Common law controls over fresh water are almost exclusively concerned with individual rights. "Owners of land on the banks of a stream have 'riparian rights' over flowing water, not to be obstructed or affected in flow or quality by, for example, introducing foreign matter or raising temperatures ...generally, pollution, that is adding something to water so as [to] adversely affect its quality can constitute nuisance, trespass or negligence" (McCalla 1995). Legal precedent in Common Law water cases has been established for stream water, ground water, and tidal waters alike.

The Banana Industry Act

The Banana Industry Act (Cap. 168) establishes a Banana Control Board. The function assigned to the Board is the power to acquire and develop land either alone or in association with others for banana production. The Board is also responsible for granting licenses for banana cultivation in designated areas. This Act establishes a government entity responsible for facilitating the exploitation of Belizean land as a means of drawing foreign capital to the country to raise the GNP and generate increased tax revenue. A community effort to monitor effects of the banana industry on their resources would probably meet with some resistance from an organization such as the Banana Control Board.

Belize's natural resource legislation has drawn some criticism. McCalla (1995) comments that ORe"major inadequacy" of the EPA is the lack of regulations to implement the provisions of the Act. Importantly, McCalla goes on to say, " one of the critical problems is that despite so much legislation there is very little enforcement," for reasons of lack of trained enforcement officers, lack of trained persons who can conduct prosecutions, low levels of fines, and lack of public education on environmental offenses. With the Department of the Environment (DOE) only recently being formed in 1993, it is not surprising that little enforcement is taking place. One would hope that the DOE is currently building political momentum and infrastructural solidity needed to enforce natural resource legislation in the future.

Protected Areas in Monkey River Watershed

Protected Area Name	Area (mi2)	Area (km2)
Bladen Nature Reserve	156	402
Maya Mountain Forest Reserve	128	332
Cockscomb Basin (In Swasey Drainage)	150	390
BFREEPrivate Reserve	2	5.2
Total	436	1129.2

Table 1.1: Protected Areas in Monkey River Drainage (Modified from Heyman *et al.* 1995)

Bladen Nature Reserve

The Bladen Nature Reserve was established in 1990 but has received no management since then. Drained by the Bladen Branch of the Monkey River, the Bladen Nature Reserve is one of least disturbed areas in Belize due to its rugged karst and granite topography and seasonal flooding. Forests of the area are intact since ancient Maya occupation a thousand years ago with diverse and healthy endemic wildlife populations and unexcavated Maya archeological sites. Illegal hunting and fishing occur regularly in the Bladen Nature Reserve from settlements along the Southern Highway.

Maya Mountain Forest Reserve

The Maya Mountain Forest Reserve consists of two land parcels, one of which is drained by the Trio Branch of the Monkey River. The reserve is managed by the Government of Belize for timber extraction. Hunters and fishermen also use this area regularly.

Cockscomb Basin Jaguar Preserve Wildlife Sanctuary

A large portion of the Cockscomb Basin Jaguar Preserve is drained by the Swasey Branch of the Monkey River. The reserve is managed by the Belize Audubon Society in conjunction with the Department of Forestry. Unlike many other designated protected areas in Belize, the Cockscomb Basin Jaguar Preserve has a well established management presence "inclUding rangers, a research station, camping area, trails, and a visitors center.

Monkey River Special Development Area

The Monkey River Special Development Area (SDA) was designated in 1993 and includes the adjacent Payne's Creek National Park to the south and the Monkey River to the confluence of the Swasey and Bladen Branches. The SDA was formed under section 19 of the Lands Utilization Act in cooperation with residents of Monkey River Village. The SDA is zoned into areas of strict and less strict reserve, with a designated agricultural zone. Through zoning the area, residents of Monkey River Village are assured protection of the diverse forests of the area as a base for ecotourism as well as access to suitable agricultural land.

Coastal/Marine Reserves

Sapodilla Cayes Marine Reserve encompasses the most heavily visited cayes in southern Belize. This marine reserve is a high management priority for the Coastal Zone Management Unit of the Fisheries Department and is also receiving attention from the Belize Tourist Board. The high visitation may be used in the future to generate funding for management of the reserve by charging entrance fees, diving fees, fishing licenses, and collecting donations (Heyman *et al. 1995).*

The Proposed Port Honduras Marine Reserve is part of the Maya Mountain Marine Area Transect.. A prominent feature of the southern Belize coastline, the port receives waters from six drainage basins. Extensive mangrove and seagrass habitat is found in Port Honduras contributing significantly to marine fisheries in the area. The marine reserve extends north beyond the bight of the port to include the mouth of the Monkey River.

Meso-American Biological Corridors Project

The Meso-American Biological Corridors Project (MBCP) is a large scale regional planning initiative to coordinate a network of connected protected areas through meso-America to ensure the maintenance of native biodiversity and evolutionary processes. Belize recently received US$l million for in-country management for the MBCP. Seventy percent of this funding is being invested for management development for the Bladen Nature Reserve in the Monkey River drainage and the neighboring Chiquibul Forest Reserve. According to a memorandum from the National Coordinator of the MBCP National Steering Committee (30 Sept. 96) the funds are intended to be "used as leverage funding to get more money to achieve the objectives of the 'bigger picture' of consolidating the National Protected Areas System Plan."

Actual management for both the Bladen Nature Reserve and the Chiquibul Forest Reserve will be over seen by the Department of Forestry under the guidance of t~e National Steering Committee. A collaboration of governmental and non-governmental organizations will undertake the detailed management planning for the Bladen Nature Reserve. The group known as the Bladen Consortium will consist of the Forestry Department, the Belize Foundation for Research and Environmental Education (BFREE), the Belize Audubon Society, an independent researcher, the Department of Archaeology, the Belize Center for Environmental Studies, and the Alcalde Association (representing indigenous Maya communities throughout Belize) (Forest Officer 1996). Responsibilities of the Bladen Consortium are to develop, implement, and periodically assess a management plan, to create a management presence in the Bladen Nature Reserve, and to recommend a long term management strategy for the protected area.

Maya Mountain - Marine Area Transect

The Maya Mountain - Marine Area Transect is the product of a 1990 Critical Habitat Survey by the Government of Belize and the Belize Center for Environmental Studies (BCES). Using rapid ecological assessment and gap analysis, 35 critical habitats were identified throughout Belize. The study identified mangrove forest and pine ridge forest as underrepresented in the Belize protected area system. The study also identified a transect of land extending from the inland Maya Mountains east to the Caribbean sea, including Port Honduras as an area of high protection value. In total the MMMAT encompasses close to one million acres including three adjacent watersheds (including the

Monkey River), five protected areas, and the proposed Port Honduras Marine Reserve. With funding from the Nature Conservancy and the US Agency for International Development, BCES compiled a multi-faceted integrated planning and management report that recommends the area be managed as a Biosphere Reserve (Heyman et al. 1995).

The MMMAT contains 29 of 78 of the natural vegetation types occurring in Belize and covers about 6 % of the ,country's land area. The total area is home to a diverse range of habitat types and associated wildlife including numerous endangered species, large and small mammals, predatory carnivores, nesting birds, and abundant small and large reptiles and amphibians. The coastal area contains "dolphin, manatee, nesting hawksbill turtles, nesting crocodiles, nesting iguanas, nesting birds and diverse fishes" (Heyman *et al.* 1995). The area gets nearly 4 m of rain annually and supports luxuriant forests. Port Honduras contains over 130 mangrove cayes, and has habitats ranging from estuarine to fully marine. The Snake Cayes on the outer edge of Port Honduras have some sandy beaches and support rich coral communities.

The largest watershed in the MMMAT is the Monkey River which has important impacts on Port Honduras coastal areas with a sediment plume reaching more that 12 miles into the sea during high flow (Heyman *et al.* 1995). Along with these sediments comes agricultural pesticides and macronutrients from upstream agricultural activities. From a water-based management perspective, the Monkey River should be the primary focus as it impacts coastal ecological processes in Port Honduras most severely.

Part 2: Monkey River Monitoring Program Design

2.1 Overview of Design Process

A volunteer river monitoring program is only a) expansive as the energy and resources invested in it. At this early point in the process, it is premature to second-guess how such a program might specifically manifest.. Instead Part 2 of this preliminary assessment will overview factors for consideration by a Monkey River Monitoring Program (MRMP) Steering Committee in the development of a monitoring program. Much planning should occur before field impact assessment to scope the study area and generate an experimental design. Once scoping and experimental design are complete and volunteers are trained, actual field data collection carl'take place. Three types of data collection that will be explored here include: (1) chemical and biological data collection to assess anthropogenic impacts on the lotic system; (2) physical data collection for monitoring long-term changes in river morphology; and (3) epidemiological data collection focusing on risks to human health from pesticide spraying and contaminated river and well water. Ideally, a river monitoring pr~gram in the Monkey River drainage will include collection of each of these types of data.

The planning process for a Monkey River Monitoring Program can be broken down into five steps (Fig. 2.1). Step 1 is the formation of a MRMP Steering Committee consisting of representatives from the local communities, government, non-governmental organizations (NGOs), scientific consultants, and project coordinators. The purpose of the steering committee is t<;monitor program development, locate resources (money, information, transportation), evaluate data, and periodically evaluate the program once it is under way. Once the steering committee is established, Step 2 is initiated; defining goals and foci for the MRMP according to preliminary assessments of the study

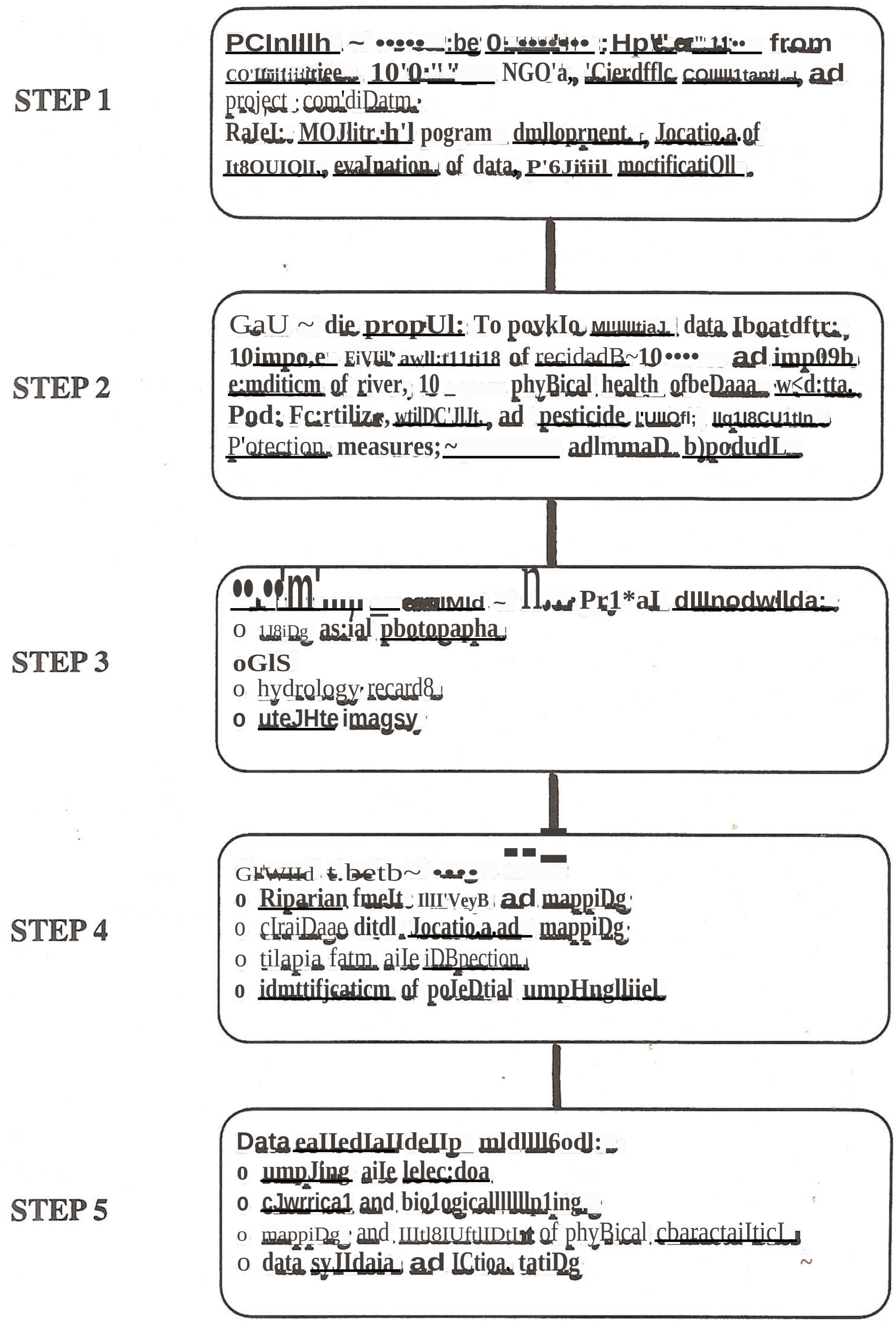

Figure 2.1: Steps in River Monitoring Program Planning

area. Step 3 is a physical preliminary assessment of the stream using remote sensing materials, history collection, and Geographic Information System (GIS) data bases. This step is intended to identify areas of potential land-use conflict and potential sampling sites. In Step 4, "hot spots" identified in Step 3 are field checked by volunteers on foot, by boat, or from the air. Specific land-use information is accurately mapped (including riparian forest clearance and location of banana and aquaculture drainage ditches) and potential sampling sites are identified and briefly evaluated. In the final step of the program (Step 5) sampling sites are established and tested for physical, chemical, and biological indicators over time. Data is then analyzed and put into a usable form for evaluation and action taking by the MRMP Steering Committee.

2.2 Step 1: Formation of a Steering Committee

The formation of a Steering Committee may well be the most important step in assembling a river monitoring program in the Monkey River drainage. Such a committee must include representatives from all communities in the catchment, conservation managers, government officials, scientific professionals, and project coordinators. The Steering Committee for the MRMP will consist of the following positions (potential candidates identified where possible):

- BFREE - Jacob and Kelly Marlin
- Edward Boles - Aquatic Ecologist
- Will Jones - Belize Naturalist; Banana farm manager
- Program Coordinator(s)
- Village Representatives from Cowpen Village, Bladen Village, Trio Village, San Juan Bosco, and Monkey River Village.
- Representative from Banderas Unidas (Banana Workers Union)
- School teachers from watershed
- BCES Representative
- Forestry Department - Conservation Division Representative
- University College of Belize - Environmental Science representative

The roles of this committee will include program development, location of needed resources, evaluation of data, and program modification/improvement. . The Steering Committee will be involvedfrom the initial planning stages through program implementation and beyond. Adaptive management of the program will occur with periodic reevaluation and modification of goals, progress, and methods. Resources needed by a MRMP will likely include funding, government technical support, and scientific expertise.

2.3 Step 2: Monkey River Monitoring Prog~am Goals.

Three goals of the MRMP are:

1. To improve environmental education of residents via training workshops, river assessment activities, and action taking;

2. To assess and improve condition of river; and

3. To assess the physical health of inhabitants of communities relative to water quality.

From information presented in Part 1, it is possible to determine focal areas of importance for monitoring. The heaviest impacts on the stream are clearly originating from the poor land-use practices by the banana industry. These impacts will be the primary assessment focus. Other areas of concern requiring secondary focus include metabolic wastes and nutrient pollution from the aquaculture facility and possibly human metabolic waste.

Three byproducts from the banana industry directly impacting the river include fertilizer runoff, pesticide runoff, and erosion/sedimentation. Effects of these non-point pollution sources are discussed in detail in Section 1.2 above. Collection activities will specifically address these three variables. If resources allow, secondary variables will be tested for, but not at the expense of primary foci of study.

2.4 Step 3: Preliminary Assessment of Physical Characteristics

Having a sound understanding of a stream's physical characteristics is essential to designing a successful monitoring program. Important information can be extrapolated from remote sensing sources such as aerial photographs and satellite imagery. If available, these sources will be used to evaluate extent of riparian forest clearing, riffle to run ratio, drainage ditch networks from banana fields and the aquaculture facility, and potential sampling sites at, downstream and upstream of "hot spots" along the Monkey River.

Attempting to assemble an accurate history of the river is also important.. Flood cycles and timing of other unusual events in the river's history can be used to piece together a hydrological history of the stream. Much of this information is locked in the memories of the people who have lived with the river for large portions of their lives. Old timers from Monkey River Village will be interviewed as part of a preliminary assessment to assemble such historical data. Other sources of historical data are the national archives located in Belmopan.

The Land Information Center (in Belmopan) and BCES (in Belize City), should be consulted for technical support using their GIS data bases. Not only will current information from these data bases need to be accessed and included in a preliminary assessment, but information generated by the MRMP must be shared for inclusion in national and international GIS databases.

Finally, Step 3 will include a detailed land tenure analysis for the catchment.. From land tenure analysis, maps showing land tenure and basic land-use information as well as important physical characteristics of the landscape will be produced. Such maps will be necessary for field checks of impact sites.

2.5 Step 4: Ground-Checks of Hot Spots

Ground checking data from remote sensing sources will be performed to verify accuracy. In the case that no remote sensing data is available, all preliminary assessment will have to take place in the field on foot, by boat, or from the air. An issue of particular importance to the Monkey River is extent and location of riparian forest clearing. Ground checks will be performed to map and assess bank erosion at sites where riparian clearing has taken place. Accuracy of mapping will be ensured by use of a global positioning system (GPS). By correlatipg land ownership with riparian forest clearing the MRMP will build a basis for legal action should such measures ever prove necessary..

Location of drainage ditches will also be correlated to a map of the stream. Drainage ditches serve as point sources of pollution during times of high surface runoff. Sediments carrying pesticides, and macro-nutrients are carried by surface water into drainage ditches and then into the stream. Drainage ditches from banana fields, human settlements, and the aqmi.culture facility will be located.

Another Step 4 activity will be to visit the tilapia farm to assess operations and protection measures and to establish a working relationship between Monkey River community members and aquaculture administrators. As mentioned in Section 1.3, tilapia are not native to the neotropics and thus great care should be taken to avoid their release into the wild. Escape prevention methods at the tilapia farm should receive constant scrutiny including periodic inspections by members of the Monkey River watershed community.

The final purpose of field checks is to identify potential sampling sites for both physical data collection and biological/chemical data collection. Sites for collection of physical data are intended to be long term and thus should be chosen with extreme care. Questions that should be ask prior to site selection include:

- What do we want to know about this stream or drainage?
- What variation (geology, elevation, land use) exist in the area?
- How can we set up the most useful comparisons with the fewest sites?
- How can this site contribute to existing or planned efforts?
- How much can be accomplished with present resources (Harrelson *et al.* 1994)?

Biological/chemical sampling sites for impact assessment will be situated bracketing impact sites. For this type of sampling three sites will be chosen: one immediately upstream of the potential impact, one immediately downstream of the impact, and one downstream of the impact as a "recovery site". All three sites should resemble each other as closely as possible to isolate the impacts of the pollution source from other variables that may hamper results (Behar 1996).

Possible sampling sites on the Swasey, Bladen, and Trio Branches will bracket banana growing areas. The uppermost banana development on the Swasey watershed will be sampled to establish a control in unimpacted conditions on the upstream side. Evaluation of potential sampling sites should take into account that sampling will be done predominantly in riffle zones. Sites will be mapped and compared to establish optimum sampling locations. Aside from stream characteristics, factors that will play into the decision include ease of accessibility and travel time to site.

2.6 <u>Step 5</u>: Sampling Design, Data Collection, and Synthesis

Thorough project pre-assessment to this point will have identified suitable sites for the establishment of permanent reference stations; impacted areas needing sampling; easily accessible and similar sampling sites within these areas for impact assessment; and variables to sample for. The discussion of methods that follows will remain general with references for more details about methods and sampling techniques.

<u>Establishment of Long Term Reference Sites for Physical Data</u>

Harrelson *et al.* (1994) in their report, *Stream Channel Reference Sites: An Illustrated Guide to Field Techniques,* review in detail the importance of permanent reference sites for establishing a baseline for long term study of a river's physical characteristics. Information generated in such a study can be useful in monitoring trends in a rivers geomorphology over time, assessing a stream's response to management, allowing comparisons between stream types, and contributing to regional, national, and international databases. Steps in the data collection process include selection of sites, mapping of sites, measurement of channel cross-section, survey of longitudinal profile of channel, stream flow measurement, bed material measurement, and permanent data filing. "With this foundation of technically correct and comparable data, we can track changes in the character of the stream"(Harrelson et al. 1994).

A suitable site for sampling should be easily accessed, but not heavily modified or impacted. The sample reach should consist of an entire meander, or two bends of the stream. Once a site has been chosen, a "monumented cross-section" should be established at a straight run between two bends. This cross section "...is the basis for delineating channel form, for measuring current velocity, and calculating discharge" (Harrelson *et al.* 1994). After rudimentary sampling site location on a map, more detailed survey work begins, mapping the site and taking channel measurements.

Impact Assessment Indicators and Methods

Table 2.1 shows primary and secondary indicators of pollutants identified in Step 2 of the pre-assessment process. Qualitative, chemical, and biological indicators will be used collectively to identify the impacts of pollutants being measured. Below is a brief description of each primary indicator and collection methods. Detailed descriptions of indicators and sampling methods can be found in Stapp and Mitchell (1995), Mitchell and Stapp (1993), and Behar (1996).

Catchment Land Use	Potential Pollutants	Primary Indicators	Secondary Indicators
Agriculture	*erosion/ sedimentaion*	*turbidity*	*benthics*
		total solids	
	pesticide runoff	*benthics*	
	nutrient runoff	*nitrates*	*phytoplankton*
		phosphates	*macrophyte*
			dissolved oxygen
			BOO
Aquaculture	*metabolic byproducts*	*fecal coliform*	*nitrates*
			phosphates
			BOO
Residential	*metabolic byproducts*	*fecal coliform*	*nitrates*
			phosphates
			BOD

Table 2.1: Pollutants, Primary and Secondary Indicators (From Stapp and Mitchell 1995)

Turbidity

Turbidity describes how particles suspended in the water column affect its clarity. It is an important indicator of suspended sediment and can be used to assess the impacts of erosion and sediment over distance and time (Behar 1996). Section 1.2 discusses the impacts of turbidity on a stream including raising stream temperatures, lowering dissolved oxygen, disrupting primary production, and affect the habitat of much aquatic biota.

Several low-costs methods exist to measure turbidity including use of a Secchi disk and use of a turbidity kit. Secchi disks cannot be used in shallow waters or in fast currents so are not the most reliable sampling device for the fast flowing waters of the Monkey River. A turbidity kit on the other hand measures turbidity by comparing the amount of turbidity of a sample with an identical turbidity-free sample. Turbidity kits can be used in shallow water and can be purchased for under US$30.

Total Solids

Total solids is a measure of the weight of organic and inorganic solids dissolved and suspended in a water sample. Like turbidity, solids suspended in the water column impact stream temperatures, dissolved oxygen levels, and photosynthesis. To measure total solids a 100 mL sample of river water must dissolved completely and the resulting residue weighed on a scale sensitive to the nearest .0001 gram. Such a scale will be found at the University College of Belize and possibly other junior colleges and high schools throughout Belize.

Phosphates

As discussed in Section 1.2, phosphorous is a "growth limiting factor" in aquatic systems and when present in raised levels, can cause large increases in growth of aquatic vegetation. Measuring for phosphates in the water is an involved process using a reagent powder to react with phosphorous in the water measured using a colorimeter or a spectrophotometer. A Hach kit is needed to perform this test (approx. cost: US$100).

Nitrates

Nitrogen is another nutrient that encourages plant growth. As discussed in Section 1.2 increased plant growth can cause cultural eutrophication which can lead to lower dissolved oxygen levels in stream water. Testing for nitrates requires a Hach kit that uses a special reagent to change the sample color to then be compared to a control sample. Hazardous waste in the form of residual cadmium results from this test. The sampling kit for testing nitrates costs approximately US$45.

Fecal Coliform

Fecal coliform bacteria are found in the feces of humans and other warm blooded animals. The bacteria themselves are not pathogenic, but are commonly found in association with pathogenic organisms and thus are an accurate measure of the probability of pathogens in water. Fecal coliform is tested by filtering river water and then incubating the filter for 24 hours to encourage growth of fecal coliform colonies. Coliform counts are measured in colonies per 100 mL and assessed using established indices. Due to the incubation step in this process and the short sample viability time between collection and incubation, this test will be difficult to perform in remote locations in the Monkey River drainage.

Benthic Macroinvertebrates

Benthic macroinvertebrates are small bottom-dwelling organisms visible to the naked eye. Benthic macroinvertebrates are an extremely important part of the lotic trophic system, connecting primary producers such as algae and aquatic macrophytes with other organisms, particularly fish. Macroinvertebrates are widely used as biological indicators of water quality and many indices have been developed to evaluate water quality on the presence or absence of certain macroinvertebrates. Macroinvertebrates are excellent for sampling pollution impacts because "They are good indicators of local conditions and site-specific impacts. They quickly integrate the effect of short-term environmental variations, and because they are not very mobile, they are easily sampled with inexpensive equipment and minimal dis~urbances to stream habitats" (Stapp and Mitchell 1995).

Limitations to use of macro invertebrates as indicators are the large number of samples that need to be collected and identified, and the fact that indices do not account for naturally imposed pressures on macroinvertebrate assemblages. With these limitations in mind, it is important to use macroinvertebrates in conjunction with other indicators to arrive at accurate test results about water quality (Stapp and Mitchell 1995).

A detailed description of bioassessment protocols can be found in Plafkin et al. (1989), *Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic macroinvertebrates and Fish.*. Belize's streams can be assessed using macroinvertebrate indices developed in the southeastern United States (due to similar speciation in aquatic systems in both places) (Boles, pers. comm.). Aquatic ecologist Edward Boles is setting a precedent for sampling protocol in Belize with his dissertation work in the Sibun River. A standardized country-wide methodology would allow for easy data comparability between streams. It is recommended that the (nearly complete) dissertation of Edward Boles be used to develop sampling protocol for the Monkey River.

Sampling techniques for macro invertebrates in wadable streams are basic and inexpensive. Devices such as kick seines and D-frame nets are easily hand made for little or no cost, and thus are an attractive option for sampling in Belize where funding is scarce for environmental monitoring. Training community members in sampling techniques would also be relatively easy compared to the use of chemical indicators requiring laboratory techniques.

Community Health Surveys

Interviews of doctors at government clinics near Cowpen Village have revealed multiple cases of chemical intoxication, respiratory illness, rashes, and skin infections from agrochemical usage in banana growing areas (Roches and Shoman 1995). With settlements literally built into the edges of frequently sprayed banana fields, human health concerns are paramount when considering banana worker villages. Ground water contamination is widely acknowledged, and sanitation facilities inadequate. Human health surveys could go a long way towards exposing violations of human rights in banana industry settlements if correlated positively to river and well water contamination.

Successful epidemiology studies have been performed by volunteers both in Vermont and along the TexaslMexico border. Volunteers were trained to avoid sampling biases in administering interviews, and data was collected to indicate: (1) what contaminants were in the water; (2) how people were coming into contact with contaminants; and (3) what illness symptoms people were experiencing (Lopez 1996). A similar program could be implemented in conjunction with the MRMP with the goal of improving the quality of life for the thousands of banana workers living in the Monkey River watershed.

Community Outreach and Volunteer Training

Having a broad and well-trained volunteer base is the keystone to any community river monitoring program. Volunteers for the Monkey River Monitoring Program will come from multiple locations including school children, village adults, United States college students, Belizean high school and college students, and European volunteer organizations. Coordinating people from vastly different age, ethnic, and educational backgrounds will be the challenge of the project coordinators.

Schools offer a rich and energetic group of volunteers. Schools within the Monkey River catchment go to the US equivalent of eighth grade. A river education unit could easily fit into a primary school science curriculum, and although the type and quality of data collected by the school children may be limited, certain activities such as weather monitoring, carefully guided macroinvertebrate sampling, and qualitative analysis activities could take place within acceptable quality limits. Reaching out to young children with environmental education is of obvious importance to ensuring a strong environmental ethic in the next generation of decision makers.

Adults from the five communities in the catchment will be excellent sources of information, volunteer energy, and leadership. These are the people with intimate knowledge of the patterns and fauna of the rivers and sea. These are also the people whose livelihoods are most at risk from polluted rivers, well water, and coastal areas. Technical data collection methods could be taught to these older members of the communities such as mapping/surveying and chemical indicator tests. Adultvolunteers can be expected to produce highly accurate data after several training sessions, and a minimum of sampling experience. Educational levels of communities in the Monkey River catchment are fairly low on average. In migrant communities, primary school will often be the highest level of education achieved, whereas in Monkey River Village on the coast, most members of the community have finished primary school and some, high school..

"Educational tourists" such as college semester abroad students visit the Monkey River watershed regularly through host organizations such as BFREE in the upper Bladen Branch. These groups of students will offer rich resources to the MRMP being highly educated and often enthusiastic about conservation. These volunteers can be utilized in multiple ways to benefit the MRMP.

In-country high school and college groups offer another rich source of intelligent and energetic youth for river monitoring. As with primary school children, river ecology can easily be worked into a high school or college curriculum with laboratory and field experiences in the Monkey River catchment.. Environmental groups at these schools are especially likely to participate in a river monitoring program.

BFREE also hosts European volunteer groups for work-service projects in remote and challenging conditions. These volunteers are often motivated by a desire to "protect the environment" and could be worked into a river monitoring program quite easily. Most of these volunteers originate from Great Britain and come through summer tour groups.

Given the diverse range of volunteer possibilities training workshops will have to be similarly diverse and flexible. For young and old volunteers alike, basic concepts in stream ecology will be taught at varying degrees of detail.. Such concepts will including the river continuum concept, trophic interactions and energy flow, habitat types and associations, and landscape linkages between terrestrial and aquatic systems, and between aquatic and coastal systems. Review of the scientific method and field methods will also be taught in workshop settings, stressing data quality requirements.

Due to the presence of both Spanish and English speakers in the catchment, educational programs will be developed in both languages. Written materials will be useful but cannot be relied on exclusively, as illiteracy ~ill undoubtedly be prevalent through some communities. Project coordinators will need be conversant in both Spanish and English.

Data Management, Action Taking, and Adaptive Management and Monitoring

Once data is acquired and analyzed, the results will allow the Steering Committee to take steps to improve river water quality. Data management and storage should be coordinated from BFREE until the program is up and running with experienced volunteers moving into program management roles. Due to the remoteness and harsh environmental conditions at BFREE to both paper and computer disks, records would have to be carefully stored ina humidity controlled environment.. It is recommended that multiple data sets be stored in different locations to ensure the security of the data.

Computer technology should be fully utilized for both processing of data and data storage. As floppy disks are easy to lose and tend to mold in the Belize climate, CD-RaMs may be the best option for storage of information as it will not be affected by climate. Recent innovations in CD-ROM technology have created a CD that can be "written to" by special hardware. Though more expensive, this option is far preferable to floppy disks.

Three types of program monitoring should take place by the Steering Committee: implementation monitoring, effectiveness monitoring, and validation monitoring. *Implementation monitoring* determines if a planned activity was accomplished. The Steering Committee will be responsible for evaluating whether planned impact assessment activities were accomplished within acceptable limits of data quality. If data quality standards were not met, the Committee will then be responsible for correcting errors in data collection and training techniq~es. *Effectiveness monitoring* is the process of determining if the MRMP' achieves the stated goals and objectives of the program. Again, the Committee will be responsible for correcting any inadequacies in the MRMP. *Validation monitoring* evaluates the validity of assumptions used in developing the program plan are correct.. Flaws in the theoretical assumptions behind the entire program would flaw every aspect of that program. For this reason, careful attention to every aspect of pre-assessment is critical (Noss and Cooperrider 1994).

Adaptive management is the process whereby the research and monitoring process continually fee~!i back upon itself by periodic scrutiny of assumptiops and methods based on current ecological knowledge. By continually evaluating the MRMP the Steering Committee will assure that the program remains on track and in-line with the goals of the program. Without adaptive management project plans stagnate, static in a fluid realm of ever-more-insightful conservation science. This role of scrutiny and modification is perhaps the most essential link to the longevity of the Monkey River Monitoring Program.

2.7 Conclusions

Part I of this document describes the Monkey River drainage as a physical, social, economic, and political land unit.. Conservation management issues within the catchment are also discussed. The commercial banana industry was clearly identified as the major stress on both aquatic and coastal ecosystems, as well as the human ecology of the area. Another potential stress is the tilapia farm on the Swasey Branch of the river.

Part 2 of this document gives an overview of the planning process for the Monkey River Monitoring Program including idealized representations of goals, volunteer activities, and sampling considerations. General methods for physical characteristic study, as well as impact assessment study based on qualitative, biological, and chemical indicators were discussed. Epidemiological monitoring was also introduced.

What are the challenges that face the formation of a Monkey River Mop.itoring Program? How feasible is such a program? Challenges to establishing the program are many including inevitable opposition by the Banana Growers Association, motivation of community members to take their health and economic conditions into their own hands, and logistical issues such as funding and technical support. Migrant communities in particular will be difficult to "break into" given the climate of fear caused by the Banana Grower Association's (BGA's) complete hegemony over the workers. With the power to terminate 400 workers instantly for unionizing, it is unlikely that migrant community members will come running to volunteer for a river monitoring program They may be more cooperative with a discreet epidemiology study however. Government favor of banana development and the BGA may be a deterrent to NGO's reliant. on government favor for their own survival. Bananas are a center piece of Belize development schemes, and rocking the boat can potentially invoke a strong response from powers benefiting from banana cultivation. Hope from within the communities lies within the solidarity of the union and the small numbers of workers who are risking their livelihoods to attain better basic rights to clean water, housing, and fair wages. It is with the Banderas Unidas that the MRMP will have to be loosely affiliated. Repercussions of such an affiliation are unknown.

Allies within the watershed are small but committed. A core of individuals from Monkey River Village understands and advocates conservation of the river, and BFREE upstream will ever remain in support of clean lotic and coastal areas. Reports from the Society for the Promotion of Research and Education indicate strong support for human rights issues such as those occurring in the Monkey River watershed relating to well-water contamination and aerial spraying of houses. BCES also has reported on poor conditions in the watershed. The strength of grassroots NGO's should never be underestimated as shown in the Sibun River watershed in the Hale case.

In conjunction with MMMAT water-based management initiativ~s and Biosphere Reserve efforts, the MRMP could well receive the conservation niche it requires to begin and thrive. Funding sources must be sought and more extensive research needs undertaken to build on this rudimentary preliminary analysis. Meticulous attention should be paid to development of chemical, biological, physical, and epidemiological survey techniques.

The time is now to foster community organization in the Monkey River watershed. The legislative framework is in order and the conservation community is supportive. Communities must motivate to build allegiances with different interest groups, initiate internal discourse on the subject, and evaluate their best course of action.

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