Jamaica Ecoregional Planning Project
Jamaica Freshwater Assessment

Essential areas and strategies for conserving Jamaica's freshwater biodiversity.

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GLOSSARY

Aquatic Ecological System (AES):- An AES is defined as geographical units having similar types of hydrology, elevation, topography and/or slope characteristics.

Caribbean Ecoregional Planning (CERP) Project: An 18-month project commenced in December 2002 and led by TNC, with the purpose of conducting ecoregional planning for the islands within the Caribbean Basin.

Conservation Target: Conservation targets are biological systems (species, ecological communities, and ecological systems) that represent the range of biological systems in a region and the natural processes that maintain them. There are two types of conservation targets:

> *System Level targets* or 'coarse filter' targets, which ensure the conservation of common and widespread species; and
> *Species Level* or 'fine filter' targets, which ensure the conservation of single species, assemblages and communities with special requirements.

Conservation Area: conservation areas are geographic areas of land and water specifically managed for the targets of biodiversity found within them.

Ecological Integrity: A conservation target has integrity when all its key ecological attributes remain intact and function within their natural range of variation. Conservation targets with integrity are resistant to change in their structure and composition in the face of natural disturbances (eg. fires, exotic species); and are resilient i.e. able to recover upon experiencing occasional disturbances.

Ecological Drainage Unit (EDU):
An Ecological Drainage Unit (EDU) is defined as groups of watersheds with similar zoogeographic histories and similar patterns of physiography, drainage density, hydrologic characteristics, and connectivity

Ecoregions:
Ecoregions are defined by TNC as areas of land and water defined by similar geology, landforms, climate, vegetation and ecological processes.

Ecoregional Planning (ERP): Ecoregional Planning (ERP) is essentially a process that selects and designs networks of conservation sites that will conserve the diversity of species, communities and ecological systems in each ecoregion.

Key Ecological Attribute (KEA):
Key Ecological Attributes are defined as the elements of biological structure and function, ecological processes, environmental regimes, and other environmental constraints that shape a biological system (or conservation target). Such attributes are described as 'key' because if any are significantly altered or eliminated, the conservation target either ceases to exist or permanently transforms into another type of system

Acknowledgements

TNC Jamaica deeply appreciates the support we received during the freshwater ecoregional assessment between January 2003 and June 2006. This freshwater assessment for Jamaica was possible only because of the contributions and critique of several persons and agencies. It drew heavily on information that was previously generated and analysed by Water Resources Authority (WRA), National Environment & Planning Agency's (NEPA) Sustainable Watersheds and Information Technology Branches, and the Ministry of Agriculture's Forestry Department. Additional support was obtained from the Jamaica Public Service Company, the National Irrigation Commission and the Mines and Quarries Division (MQD) of the Ministry of Land and the Environment.

We would also like to thank some individuals who were particularly supportive; Michelle Watts and Andreas Haiduk of WRA; Lisa Kirkland, Thera Edwards, Marc Rammelaere, Tanya Hay of NEPA; Dale Reid, Sean Hudson and Owen Evelyn of Forestry Department; Dr. Eric Hyslop, Prof. Jasminko Karanjac, Dr. Anthony Greenaway, Sheries Simpson and Francine Taylor of the University of the West Indies; and Ricardo Smalling of MQD. We also offer our sincere gratitude to Dr. David Lee for his generous and invaluable support for this project throughout the 18-month period.

Executive Summary

The Jamaica Ecoregional Plan (JERP) is an in-depth analysis of conservation areas and strategies necessary for the survival of Jamaica's freshwater, marine and terrestrial biodiversity. The JERP, first developed in June 2006, is the culmination of a three year effort involving the collection, analysis and synthesis of available biological and socio-economic data relevant to biodiversity conservation on the island and its waters. The 2006 JERP was led by The Nature Conservancy Jamaica Programme and supported by a multidisciplinary group of local and international scientists, technicians and conservation practitioners.

Ecoregional planning is a science-based and data-driven activity aimed at developing shared goals and strategies for effective biodiversity conservation. *Effective Conservation* envisions that there will be places where species, natural communities, and ecosystems are viable, threats are adequately mitigated, abated or prevented, and the conservation management status is adequate to ensure the long-term persistence of biodiversity. ERP provides a strong rationale for the conservation investments of public and private organisations, on a local, regional and international scale. The objectives of the JERP are:

1. To design a network of conservation areas that will conserve the diversity of species, communities and ecosystems in Jamaica.
2. To guide Jamaica's conservation priorities and actions under the Convention on Biodiversity.
3. To provide a scientific basis and methodology for island-wide conservation planning.

The planning was conducted for three realms; freshwater, terrestrial and marine and then consolidated into a cohesive vision, framework and action plan for conservation. Jamaica's freshwater ecosystems have not been as well studied or protected as terrestrial and marine systems. However, past assessments have recognised Jamaica's freshwater biodiversity as regionally important and characterised by moderate to very high rates of endemism (i.e. many species are unique to the island). Moreover, the healthy ecosystems that safeguard the survival of these aquatic and semi-aquatic species also provide the country's clean water and food and moderate coastal systems. Freshwater ecosystems therefore play an important role in Jamaica's economy and culture.

This report provides details about the context, methods and results of the freshwater assessment. **Chapter one** introduces the Jamaica freshwater ecoregion and the contextual basis for the JERP. **Chapter two** describes the technical approach for the assessment which is an adaptation of ecoregional planning methods to the Jamaican and freshwater contexts.

The stepwise methodology produced a Vision for Freshwater Biodiversity Conservation in Jamaica presented in **Chapter three**. This vision outlines the

conservation areas, strategies and stakeholders that would protect at least 10% of Jamaica's freshwater biodiversity. These conservation areas are areas that are or should be specifically managed for conserving biodiversity features and the ecological processes that support them. Conservation areas may or may not be protected areas however it is expected that they would inform or support the design of protected areas. GIS-based computer software and a watershed prioritisation model were used to determine freshwater conservation areas.

Steps in Ecoregional Planning for Freshwater Ecosystems
1) Collect and analyse information on freshwater habitats, species, human activities, protected areas and conservation projects
2) Establish a classification framework for freshwater biodiversity.
3) Select and map conservation targets: Freshwater ecosystems and species.
4) Develop conservation goals: The amount and distribution of biodiversity to be conserved.
5) Conduct threats assessment: Status of human activities that impact freshwater biodiversity.
6) Assess ecological integrity of conservation targets
7) Assess effectiveness of current Protected Area network: to establish priorities for protection.
8) Design conservation areas network
9) Develop conservation strategies

Jamaica, as a signatory to the CBD, has committed to protect at least 10% of its terrestrial, freshwater and marine biodiversity in ecologically representative protected areas. JERP analyses have prioritised the freshwater ecosystems within six watershed management units as ecologically significant freshwater conservation areas that would conserve at least 10% of Jamaica's freshwater biodiversity.

Jamaica's High and Medium freshwater conservation areas

Priority	Conservation Area	DESCRIPTION
High Priority (Together these areas meet the 10% conservation goal and	Black River	This includes the Black River main-stem, Upper and Lower Morasses, wetlands, coastal springs, and the freshwater lake in South-central St. Elizabeth
	Cockpit/Martha Brae	Includes Cockpit Country karstic systems, upper Martha Brae watershed and river main-stem, and Falmouth wetlands.

ecologically significant goals)	Northeast Portland	Includes upper Rio Grande and Drivers River watersheds Rio Grande main-stem and coastal springs and wetlands in Drivers River.
	Rio Bueno/White River	Upper Rio Bueno watershed, Rio Bueno main-stem and coastal springs, upland wetlands and ponds in White River watershed.
Medium Priority	Swift River	Upper Swift River Watershed, Swift River main-stem and coastal springs.
	Portland Bight	Lower Rio Cobre and Lower Rio Minho watersheds.
	Negril	Coastal Negril, Negril Morass and Fish River Hills
	Upper Cabarita/ Dolphin Head	Includes Upper Cabarita watershed and Cabarita main-stem.

JERP conservation strategies are site and countrywide objectives (in the table below) and actions that would protect or restore biodiversity health and abate threats.

	Summarised JERP freshwater conservation objectives
1. Policy-based actions	*Improve policy framework for conservation and develop management and restoration plans for priority conservation areas:*
2. Communication and Education-	*Improve technical capacity and public awareness in support of freshwater conservation*
3. Research actions	*In collaboration with the University of the West Indies, design an applied National Biodiversity Research framework which will underpin and inform Jamaica's biodiversity conservation and management strategies and address important conservation gaps (species, communities, important ecological phenomena)*
4. Conservation Area Management	*Promote protected areas as **ecologically functional** land and seascapes and as a platform for managing and rehabilitating representative freshwater ecosystems.*
5.Enforcement and Compliance	*Strengthen existing structures to ensure compliance with environmental statutes in support of freshwater conservation particularly in freshwater conservation areas.*
7. Conservation Funding	*Raise funding and in-kind contributions to support priority conservation strategies.*

Chapter 4 summarises the preceding information and points the way forward to achieving the top recommendations of the JERP in the short and medium term.

Chapter 1. Introduction & Overview

In Jamaica and the rest of the Caribbean, freshwater biodiversity has been seriously under-represented in protected areas and conservation activities (Olson, *et al* 1998). A 1995 workshop on freshwater biodiversity in Latin America and the Caribbean assessed Jamaica as a regionally important centre for the conservation of freshwater biodiversity. However the conservation status of the island was considered to be endangered in terms of its ability to maintain the habitats, water quality and hydrographic integrity necessary for the long-term survival of freshwater biodiversity (Olson *et al op cit*). There is therefore a critical need to improve the conservation status of Jamaica's freshwater biodiversity. This report gives an account of planning exercises towards this end.

The Jamaica Ecoregional Planning Project (JERP) began as part of the Greater Caribbean Ecoregional Assessment (GCERA) in 2003. Jamaica, distinguished by the uniqueness of its biodiversity, with several globally important endemic plants and animals was selected for in-depth analysis as part of the GCERA. This in-depth analysis of conservation areas and strategies necessary for the survival of Jamaica's freshwater, marine and terrestrial biodiversity is called the Jamaica Ecoregional Plan (JERP).

Ecoregional planning is a science-based and data-driven activity aimed at developing shared goals and strategies for effective biodiversity conservation. ERP provides a strong rationale for the conservation investments of public and private organisations, on a local, regional and international scale.

Ecoregional planning has been the first conservation planning exercise to explicitly incorporate the Jamaica's freshwater biodiversity. The JERP, first developed in June 2006, is the culmination of a three year effort involving the collection, analysis and synthesis of available biological and socio-economic data relevant to biodiversity conservation on the island and its waters. The 2006 JERP was led by The Nature Conservancy Jamaica Programme and supported by a multidisciplinary group of local and international scientists, technicians and conservation practitioners. Even with limited information on aquatic species it has been possible to outline a framework for freshwater conservation using existing information on Jamaica's hydrology, geology, topography and socio-economic realities.

1.1 Planning Objectives

The goal of conservation planning on any scale is to identify, focus and guide conservation actions and priorities. According to *Designing a Geography of Hope* (Groves, *et al*, 2000), the goal of ecoregional planning (ERP) is

> "to identify areas of conservation importance that contain multiple viable examples of all native plants,

> animals, ecological communities and ecosystems across important environmental gradients."

JERP objectives are detailed in Box 1.

Box 1: *Objectives of the Jamaica Ecoregional Plan*

1. To design a network of conservation areas that will conserve the diversity of species, communities and ecosystems in Jamaica.
2. To guide Jamaica's conservation priorities and actions under the Convention on Biodiversity (CBD).
3. To provide a scientific basis and methodology for island-wide conservation planning.

1.2 Planning Context for freshwater biodiversity conservation in Jamaica

As a Small Island State (SIDS) Jamaica is completely surrounded by salt water, and relies greatly on land-based freshwater (Karanjac, 2003). Consequently, Jamaica's size and level of economic development present water management and water access challenges that impact freshwater biodiversity. The ERP was conducted in this context and takes into account biophysical phenomena such as climate, topography and disturbance, and socio-economic realities such as population distribution, natural resource exploitation and policy. These are outlined below.

1.2.1 Biophysical Context

Jamaica is an oceanic archipelagic state which includes the main island called Jamaica and outlying cays and banks. The main island measures 230 km long and has a maximum width of 80km. Jamaica is a mountainous island with over sixty percent of the island being more than 230m above sea level. The mountains are concentrated along a central ridge along the WNW-ESE axis of the island. The mountain ranges in the east of the island, generally have elevations in excess of 1000m asl, and are primarily composed of igneous and metamorphic rocks. The western two-thirds of the island comprise limestone and karstic landforms with broad coastal plains in the south (WRA, 2006, NBSAP 2003).

Geology: Jamaica has an igneous and metamorphic core, covered by limestone deposited during periods of marine submergence. More than 66% of Jamaica's surface is covered by Tertiary limestones. The remaining 33% is covered by igneous and metamorphic rocks, shale, and alluvium cover. The soils of the country reflect the underlying geology: In the upland plateaux for example, soils are formed from weathered limestone and constitute approximately 64% of the island's soil, while the alluvial soils of the flood plains, river terraces, inland valleys and coastal plains, constitute approximately 14%.

Topography: The country's topography consists of a highland interior, formed by a backbone of peaks, hills and plateaux running east-west along the length of the island, skirted by flat coastal plains. The highest peaks are in the east, with the tallest, Blue Mountain peak reaching a maximum height of 2,256 m. The central and western parts of the island are mainly limestone hills and plateaux. The plateaux are dissected by faults and have been karstified to varying degrees. The most developed karst topography is in the Cockpit Country. It is an important ecological area of the country and is still relatively undisturbed.

The coastal plains are narrow on the north coast but tend to be wider along the south coast. These include alluvial areas such as the plains of Clarendon, St. Catherine and St. Andrew. There are some extensive wetlands on the coastal plains. These include the Black River Upper and Lower Morasses, the St. Thomas Great Morass, West Harbour and the Negril Morass. In addition to coastal lowlands, there are three interior valleys.

Climate: Jamaica has a tropical maritime climate which is influenced by northeast trade winds, land and sea breezes. In the cooler months of January and February, the average temperature is approximately 25° Celsius (C). Temperatures in the warmest months, July and August, range from 28°C to 30°C. Temperature is significantly affected by altitude. In the higher elevations of the Blue Mountains and some plateaux, temperatures may be as much as 15 degrees cooler than the lowlands. Rainfall is marked by monthly, annual and spatial variability. The average annual rainfall for the country is approximately 200 cm with peaks in May and October. The northeast portion of Jamaica receives the highest annual rainfall, which is in excess of 330 cm. Areas in the southern coastal plains receive less than 127 cm annually. Heavy storm-related rainfall may also occur during the annual hurricane season (June to November).

Hydrology: Jamaica's land formations give rise to surface drainage through a large network of streams and rivers. On the Blue Mountain side of the island, surface drainage predominates and there is a dense network of rivers and streams. The remainder of the island is composed of limestone with a few scattered occurrences of igneous and metamorphic rocks. Here surface drainage is less dominant and limestone aquifers and subterranean rivers are common. Limestone aquifers provide the main source (84%) of Jamaica's freshwater resources, while the remaining 16% is provided by surface water.

The island is divided into 26 Watershed Management Units (WMUs) containing over 100 streams and rivers (Map 1). These WMUs are essentially composites of watersheds that fall within 10 hydrological basins (regions). Ten watersheds have been deemed in critical condition: Hope, Swift, Wag Water, Rio Cobre, Yallahs, Rio Minho, Buff Bay, Oracabessa, Morant, and Rio Grande Rivers. Rehabilitation of these watersheds has been assigned a high priority by the Government.

Map 1: Jamaica's 26 Watershed Management Units

<u>Freshwater biodiversity</u>: Information on Jamaica's freshwater species and ecosystems is limited. Furthermore, many if not most rivers, ponds and wetlands have been modified or degraded before an inventory of their biodiversity has been made. Jamaica has been rated fifth in islands of the world in terms of endemic plants. There is also a high level of endemism for many species of animals including snails, terrestrial and freshwater grapsid crabs, amphibians, reptiles, and land birds (NBSAP 2003). It is unclear how much of this endemism is reflected in Jamaica's freshwater biodiversity.

However, there is some information available for some studied groups for example, freshwater fish (Caldwell, 1966), shrimp (Hunte, 1976 & 1978), grapsid crabs (Diesel *et al*, 2000), caddisfles, and dragonflies. Some of these publications on Jamaica's freshwater fauna indicate high rates of endemism among obligate freshwater macrofauna (i.e aquatic organisms confined to freshwater habitats). For example over half of Jamaica's 55 native species of caddisflies are endemic to the island, (Flint 1968, Botosaneanu & Hyslop 1998 and 1999) and three of Jamaica's six native fish species are endemic to the island, some to only a few watersheds. The NBSAP further states that Jamaica's freshwater biodiversity is highly threatened by pollution, dams and sedimentation due to the very intimate relationships between humans and freshwater ecosystems (Groves, 2003).

There are three endemic freshwater fish species: *Cubanichthys pengellyi*, *Gambusia wrayi* and *Limia melanogaster*. Little information is available on the ecology of these endemic species or on the freshwater ecosystems that sustain them. Two families of freshwater shrimp are found in Jamaica, Atyidae, which includes eight species, and Palaemonidae which has six species including the endemic cave shrimp *Troglocubanus jamaicensis*. The early stages of the life cycle of many these shrimps require a saline environment. This pattern of migration between freshwater and coastal/estuarine environments is also reflected in other fish species, for example *Agnostomus monticola*, and the neritid snail *Neritina punctulata*.

Ecosystem services Artisan and subsistence fisheries utilise these resources which are of considerable economic and nutritional importance to some communities. There is one endemic freshwater turtle, *Trachemys terapen* (Slider Turtle) in Jamaica.

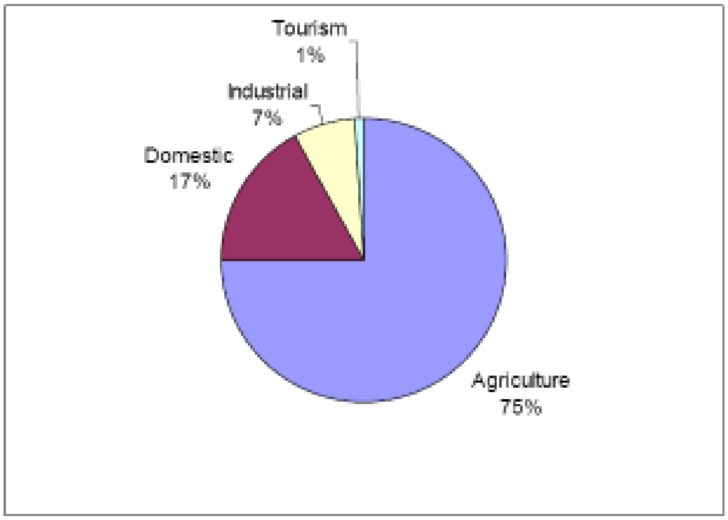
1.2.2 Socio-Economic Context

<u>Population</u>: Jamaica has been settled since around 600 A.D. The population has grown steadily since then, and the present number is 2.6 million people (STATIN 2005). The overall population density is 240 persons per km^2. This population is unevenly distributed with 45% of the population is concentrated in Kingston, the capital city and the wider Metropolitan Area.

<u>Economy</u>:
Natural resources form the basis of the Jamaican economy with agriculture, tourism and mining among the top foreign exchange earners and employment sectors (STATIN, 2005). The pattern of economic development and urbanisation has contributed substantially to the destruction of biodiversity. Initially, the increasing demand (in Europe) for sugar led to the development of estates for the cultivation of sugar cane in the lowland areas of the island. Later, agricultural production expanded to include crops such as bananas, coconuts, coffee and citrus. This agricultural development required the clearing of primary forests and was ecologically very destructive.

Jamaica seems to be well endowed with freshwater resources, however with 1512 cubic metres of water per person per year, Jamaica is experiencing moderate water stress according to the water Resources Authority (2000). Seventy-five percent of Jamaica’s freshwater is consumed by the agricultural sector and there is a need for greater water efficiency in this part of the economy.

Figure 1: Exploitable Freshwater Resource according to Sector in Jamaica



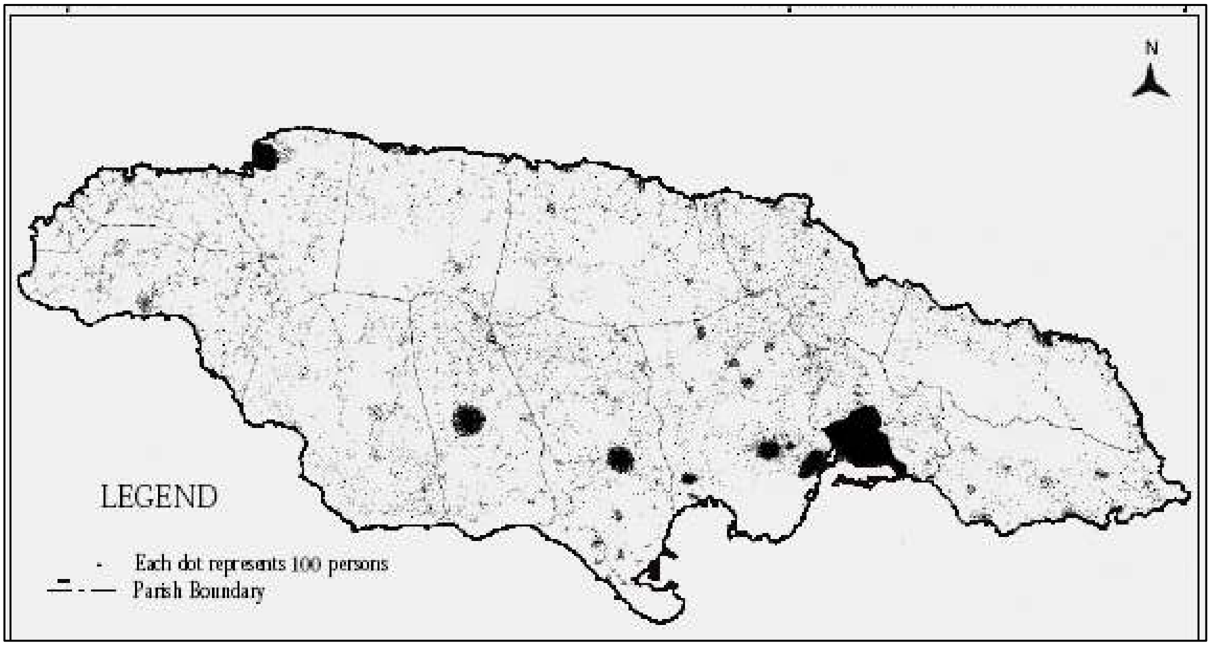
Source: Jamaica National Environmental Action Plan 1999-2002

Institutional and legislative framework: According to the NBSAP, there are about 52 pieces of legislature that relate to the management of the environment. These are fragmented and do not comprehensively protect ecosystem diversity, species diversity or genetic diversity. Table 1 shows the main legislation that are relevant to freshwater conservation in Jamaica. Even though there are legislative acts pertaining to watersheds and water, there are none that govern rivers or wetlands specifically.

Table 1: Jamaican legislation relevant to freshwater biodiversity conservation (adapted from WRA, 2005)

Act	Year	Description
Forest Act	1996	Soil and Water Conservation
Water Resources Act	1995	Manage, protect and allocate water resources
Watershed Protection Act	1963	Water conservation
Natural Resources Conservation Act	1991	Licensing, quality protection, monitor effluent discharge, designate parks and protected areas.
Rural Agricultural Development Act	1990	Forestation, extension services, crop and animal production.
Litter Act	1986	Solid wastes
Public Health Act	1985	Waste Disposal, animal housing and slaughterhouses
Quarries Control Act	1983	Quarry licenses and operations
Mining Act		Governs directions for mining and

		reclamation of mined lands
Land Development and Utilization Act	1966	Land acquisition
Flood water Control Act	1958	Regulates public streams, keeps water courses clean
Town and Country Planning Act	1958	Rights to, use and maintenance of public water,
Wildlife Protection Act	1945	Governs fishing practices in aquatic ecosystems.



Map 2: Population distribution in Jamaica (NBSAP 2003)

1.3 Planning Team

The core team for the freshwater assessment included CERP's freshwater team lead, the author and freshwater conservation specialist of TNC Jamaica, the CERP GIS coordinator and one consultant contracted to help conduct the viability assessment. The freshwater team used workshops of 8 to 15 people, questionnaires, and one-on-one consultations to review JERP results and methods and to obtain additional information (see Appendix 9 for a list of JERP freshwater review meetings and reviewers.

	Name	Title
Core Team	Kimberly John,	TNC Freshwater Conservation Specialist
	Francisco Nunez,	TNC, Dominican Republic Programme

	Name	Title
		(Conservation Science Director)
	Sheries Simpson	UWI, Post-graduate student and viability analysis consultant
Technical Support	Steve Schill,	TNC, Senior Geospatial Scientist
	Matthew McPherson,	Socio-Economic Analysis consultant
	Rick Tingey,	GIS technical consultant
	Maarten Kapelle,	TNC, Regional Science Director
	Nathalie Zenny	TNC, Conservation Planner
Other technical contributors	Eric Hyslop,	UWI, Senior lecturer
	Andreas Haiduk,	WRA,
	Michelle Watts,	WRA,
	Thera Edwards,	NEPA/ Terrestrial JERP analysis consultant
	Carla Gordon,	NEPA, Protected Areas Branch manager
	David Reid,	NEPA, Integrated Watershed and Coastal Zone Branch
	George Schuler	TNC, Programme director

Chapter 2. Technical Approach

The ecoregional assessment generally followed the methodology described in *Designing a Geography of Hope* (Groves *et al*, 2000) with some fine-tuning to reflect the Jamaican context and the guidelines outlined in the *Core Principles and Standards for Ecoregional Planning* (an unpublished document circulated by TNC's Global Priorities Group). Additional inputs on the process were obtained from the small local freshwater science community through workshops of 8 to 15 people, questionnaires, and one-on-one consultations. The freshwater assessment was completed in a series of steps outlined in Box 2. The results of each step in the process were then reviewed by local experts and TNC planners.

Box 2: *Steps in Ecoregional Planning for Freshwater Ecosystems*
1) Collect and analyse information on freshwater habitats, species, human activities, protected areas and conservation projects
2) Establish a classification framework for freshwater biodiversity.
3) Select and map conservation targets: Freshwater ecosystems and species.
4) Develop conservation goals: The amount and distribution of biodiversity to be conserved.
5) Conduct threats assessment: Status of human activities that impact freshwater biodiversity.
6) Assess ecological integrity of conservation targets
7) Assess effectiveness of current Protected Area network: to establish priorities for protection.
8) Design conservation areas network
9) Develop conservation strategies

2.1 Information Gathering

JERP is an important step towards assembling a national database of biodiversity information in a GIS format. Data gathering was by far the most time-consuming step in the planning process because there is no single repository of the physical, ecological and socio-economic information relevant to freshwater systems. Furthermore, GIS based data is very limited. Data gathering is an ongoing process, and will continue at TNC as more data are generated and the tools for data-processing advance.

Hydrological and land-use information were the foundation of all further analyses and were obtained from Water Resources Authority, National Environment and

Planning Agency, and Forestry Department. Additional information on infrastructure was obtained from other government and private agencies. Biological information was sourced from published scientific literature and expert advice. Most of the information was stored in spatial format as layers in a GIS database (in a JAD 2001 projection) available at the Jamaica office of The Nature Conservancy and online at http://maps.cathalac.org/website/tncmaps/tncmain.html. Some freshwater information is also available in spreadsheet format. Detailed information on data sources and data processing is provided in Appendix 1.

2.2 Freshwater Classification Framework

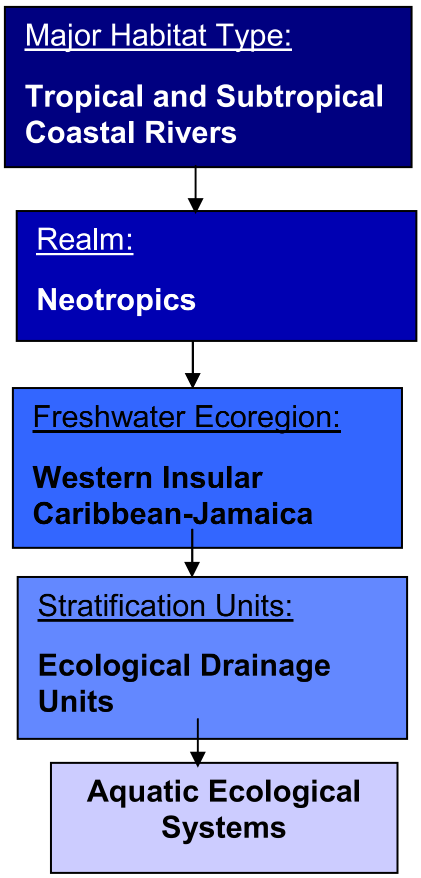


Figure 2: Hierarchical freshwater classification

One of the main purposes of ecoregional planning is to identify areas of importance for biodiversity. Since this process was new for Jamaica, the planning started by developing a classification framework for selecting freshwater conservation targets.

A hierarchical classification framework was developed to reflect the ecological gradients and patterns that exist on regional, island and local scales (Figure 2). This stratification is necessary in order to account for spatial and genetic variation and to ensure representation and resilience, particularly as it relates to distribution of risks such as disease or natural disturbances such as hurricanes.

(a) The Caribbean Basin was first stratified into **freshwater ecoregions** based on existing knowledge of the broad patterns of biogeography (Map 3). Mainland Jamaica was identified as its own freshwater ecoregion by both WWF (Olson *et al,* 1998) and the TNC ecoregional planning team.

(b) Freshwater ecoregions were subsequently divided into **Ecological Drainage Units** (EDUs), defined as "*groups of watersheds with similar zoogeographic histories and similar patterns of physiography, drainage density, hydrologic characteristics, and connectivity*" (Map 4). The Jamaica freshwater ecoregion was stratified into two Ecological Drainage Units (EDUs): 1) the Blue Mountains and 2) the Western Limestone Complex. EDU characteristics and criteria are given in Table 2.

(c) Finally preliminary **Aquatic Ecological Systems** (AES) were drafted for Jamaica according to the stratification model in Figure 3. AES were defined as "*geographical units having similar types of hydrology, elevation, topography and/or slope characteristics*". AES's were then refined to form the coarse-filter targets and are assumed to represent the main freshwater habitats across the island.

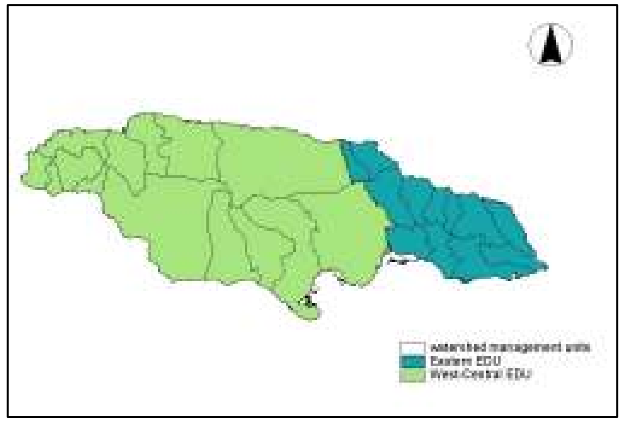
Table 2: Description of Jamaica's two Ecological Drainage Units

Ecological Drainage Unit	Characteristics	Watershed Management Units
Blue Mountain EDU	➢ Regional preference of five of Jamaica's 14 shrimp species (*Atya innocuous*, *A. lanipes*, *A. scabra*, *Micrataya poeyi* and *Macrobrachium heterochirus*) (Hunte 1978)* ➢ Drainage basins with high drainage densities, low hydrologic connectivity between basins and a volcanic/metamorphic hydrogeology. ➢ The rivers in this EDU are relatively short and fast-flowing with high gradient, high altitude headwaters	The Blue Mountains includes the following watershed management units: Oracabessa-Pagee River, Wagwater River, Pencar-Buff Bay River, Spanish River, Swift River, Rio Grande, Driver's River, Plantain Garden River, Morant River, Yallahs River, Hope River, Rio Nuevo
Western Limestone EDU	➢ Regional preference of four of Jamaica's fourteen freshwater shrimp (*Macrobrachium acanthurus*, *Jonga serrei*, *Potimiron mexicana*, *Troglocubanus jamaicensis*) (Hunte *op cit* and JCO, 2005)* ➢ Endemic fish distribution is concentrated within this EDU in southern and western watersheds. ➢ Drainage basins with low drainage densities, high hydrological connectivity between basins and a predominantly karst limestone hydrogeology. ➢ The rivers in this EDU are longer than those in the east with better developed floodplains and associated wetlands. There is also significant underground drainage.	The Western limestone complex EDU encompasses the following watershed management units: Gut-Alligator Hole River, Black River, Deans Valley River, Cabarita River, New Savanna River, South Negril-Orange River, Lucea River Great River, Montego River Martha Brae River, Rio Bueno-White River,

* Three shrimp species show no regional preferences (*Macrobrachium faustinum*, *M. carcinus* and *Xiphocaris elongata*) and there is little evidence on the distribution of *Macrobrachium crenulatum* and *Potimirim americana*.

Map 3: Stratification of the Caribbean Basin into Freshwater Ecoregions

Aquatic Ecological Systems were identified based on their hydrology (i.e. flow characteristics), size (stream order), elevation, and hydrogeology. It was assumed that these factors determined the composition and structure of the aquatic communities and therefore served as abiotic surrogates of biotic realities.

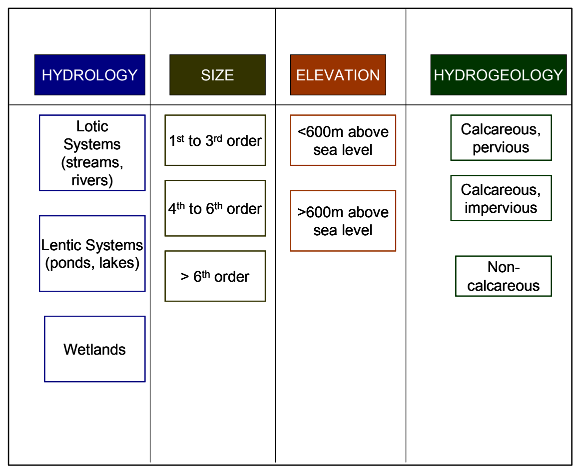


Map 4 Ecological Drainage Units of Jamaica

2.3 Conservation Targets

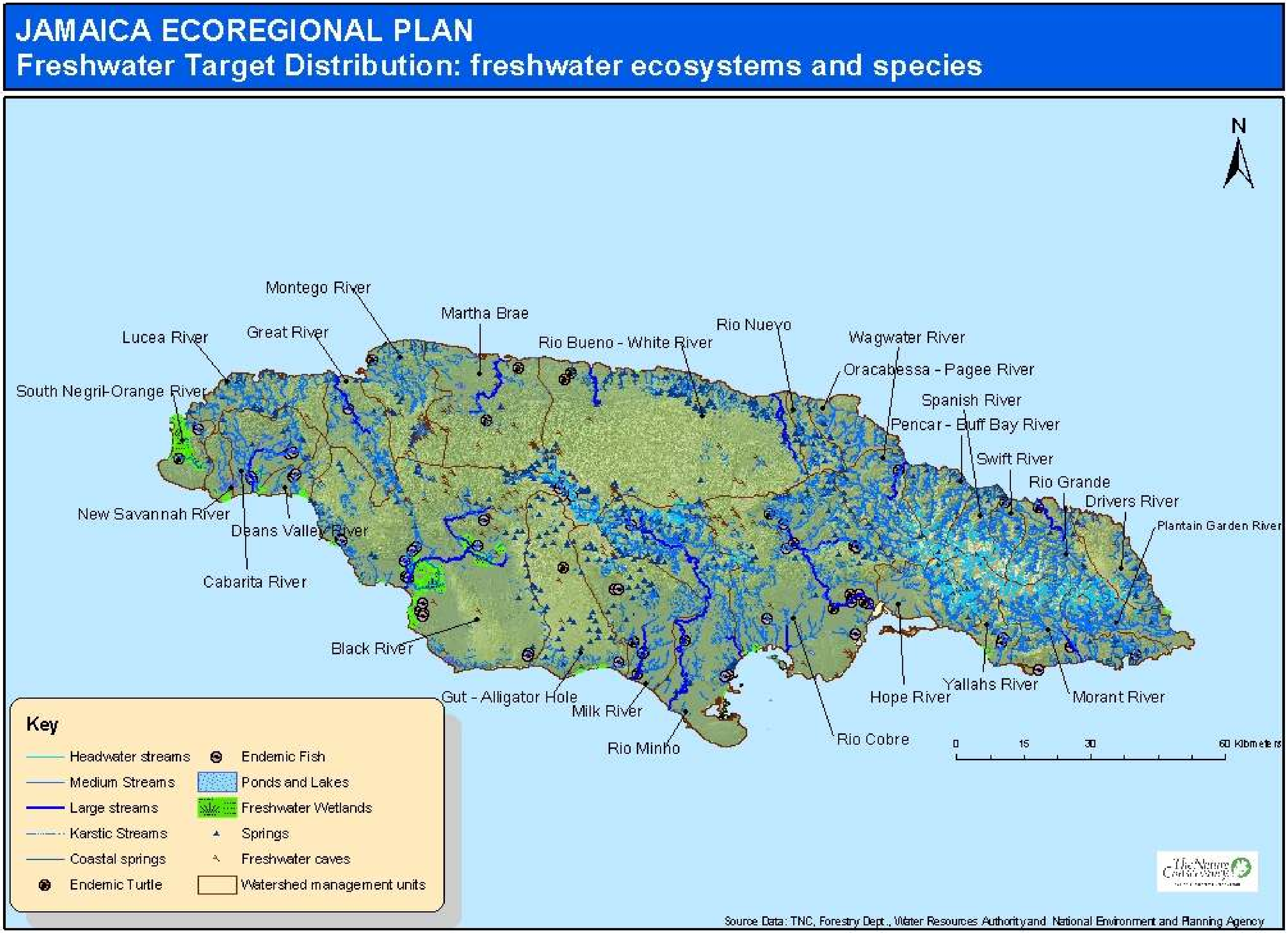
Identifying and mapping native species, communities and ecosystems was a focal activity in ERP and the foundation for all further planning activities. Selected biodiversity features (species, communities and ecosystems) are termed *conservation targets*. Conservation targets help to focus conservation planning and activities by representing the sum biodiversity in an ecoregion as well as the underlying ecological processes that sustain it.

Figure 3: A freshwater ecosystem stratification model for Jamaica.



Two types of targets were selected:
i. Coarse-filter targets: These are freshwater habitats (in this case AESs) such as stream networks, lakes or wetlands. Focussing on these habitats ensures the conservation of the majority of biodiversity, i.e. common and widespread species.
ii. Fine-filter targets: These are represented by single species, assemblages, or communities not adequately represented in single AESs. These are species which by virtue of their peculiar ecology or levels of endangerment, may not be captured in the coarse-filter targets. Endangered, endemic, declining, and otherwise unique (such as migratory species) species are candidates for species targets.

<u>Coarse-filter Targets (freshwater ecosystems)</u>
Nine freshwater ecosystems were derived from the preliminary AES and were stratified across the two EDUs to produce 17coarse-filter targets. The freshwater ecosystems were then mapped in GIS format using existing data from the Forestry Department, Water Resources Authority and National Environment and Planning Agency as outlined in Appendix 2.



Map 5: Map showing the distribution of freshwater targets across Jamaica

Fine-filter targets (Freshwater species)
Priorities for freshwater species-level targets include endemic and endangered species such as those red-listed by IUCN, specialised communities such as those inhabiting tank bromeliads or hot springs. The literature search for Jamaica's freshwater species targets revealed ecological information on endemic caddisflies, (Flint 1968, Botosaneanu and Hyslop 1998 and 1999), endemic crabs (Diesel 2000) and migratory freshwater shrimp (Hunte,1976 and 1978,) and wide ranging species such as *Anguilla rostrata* (American eel), and *Anguilla monticola* (Mountain mullet) (Aiken1998). However, there was very little comprehensive and up-to-date information on the islandwide distribution of most freshwater species. Because of this limited information, only five species-level targets were identified and mapped. These targets are all vertebrates and include Jamaica's four endemic fish species (*Gambusia melapleura*, *G. wrayi**, *Limia melanogaster* and *Cubanichthys pengelleyi/ Cyprinidon jamaicensis*) (Lee, Platania, & Burgess, 1983) and the endemic pond turtle (*Trachemys terrapen*) (Schwartz and Henderson 1991)

Table 3: Coarse and Fine-filter freshwater targets for Jamaica

	Freshwater Conservation Targets
Blue Mountain EDU	Small high altitude streams
	Med-sized, low altitude streams
	Large, low-altitude streams
	Small coastal springs and streams
	Freshwater wetlands
	Permanent and ephemeral ponds
	Springs
	Freshwater caves
West/Central EDU	Small, high altitude non-karstic streams
	Large low-altitude streams
	Karstic aquatic systems- *freshwater caves, springs and karstic streams*
	Small coastal springs and streams
	Permanent and ephemeral ponds and lakes.
	Freshwater wetlands
	Med-sized, low altitude, non karstic, streams
Fine Filter	Endemic Fish: *Gambusia melapleura, Gambusia wrayi, Limia melanogaster, Cubanichthys pengelleyi.*
	Endemic turtle: *Pseudemys terrapen*

2.4 Freshwater Conservation Goals

Conservation goals were defined as the quantity and distribution of targets necessary for Jamaica's freshwater biodiversity to sustain itself in the long-term (i.e. >100 years). Quantitative conservation goals were determined and modelled for all freshwater ecosystem and species targets (Appendix 3). Since minimum dynamic size and other thresholds were unknown for freshwater biodiversity in Jamaica, three quantitative goal scenarios were proposed based on the informed opinions of the planning team and on TNC and IUCN guidelines.

Distribution goals were represented as the spatial arrangement of target occurrences necessary to ensure replication and representation across all ecological contexts in the island. This was achieved by the previous step of stratifying Jamaica into EDUs thus ensuring that examples of freshwater ecosystems would be conserved in both the Blue Mountains and Western Limestone Complex.

Table 4: Quantitative conservation goals for freshwater biodiversity

Goal Scheme	Explanation
10%	10% of the total amount of each target is included in the conservation portfolio (recommended by CBD for all major habitat types and accepted as a minimum goal by TNC)
20%	20% of the total amount of each target is included in the conservation portfolio
Target-specific	At least 10% of each target is included in the conservation portfolio. However, higher goals are assigned to more localised and less abundant targets. (Groves *et al*, 2000)

After modelling the conservation areas arising from these goal scenarios, it was realised that the adaptive goals resulted in the most ecologically sound designs. This is because the 10 and 20% goals fragmented fluvial systems, particularly large rivers where several lowland rivers, for example Rio Grande or Black River, individually accounted for more than 20% of the total.

2.5 Threats and Opportunity Assessment

2.5.1 Mapping and Assessment of Threats to Freshwater Systems

Threats were defined as human activities that drive the alteration of the Key Ecological Attributes (KEAs) of conservation targets beyond their range of natural variation. KEAS are defined as critical patterns of biological structure and function, critical ecological processes, environmental regimes, and other environmental constraints that shape a biological system (or conservation target). Threats classes were determined based on the IUCN (2004) threats classification framework. Five of these threat classes were then mapped using FD 1998 Land Use layers and dams data from the NIC, JPS, and NWC and sewage outfall data from WRA. Information on sand-mining was obtained from the Mines and Quarries Division (Table 5).

Table 5: Threats to Jamaica's freshwater biodiversity

Threat class (IUCN)	Activity	Mapped Indicators
Agriculture	Crop cultivation:	Banana and sugar cane plantations, Small scale agriculture and grasslands, Tree crops (coffee, citrus) and agro-forestry
	Aquaculture	*Not Mapped*
	Livestock farming	*Not Mapped*
Point source pollution	Bauxite processing	Processing plants, mud lakes
	Sewage	Sewage outfalls, latrines
	Factory waste	Industrial waste outfalls
	Landfill effluent seepage	*Not Mapped*
Infrastructure	Human settlement	Urban areas
	Dams	Hydro-electric, irrigation and water storage dams
	Roads	*Not Mapped*
Resource Extraction	Water abstraction (excessive)	Surface Diversion, water use in drainage basins
	Over-fishing :fish (tilapia, mullet, etc), crustaceans (shrimp, crayfish), bussu (neritidae)	*Not Mapped*
	River poisoning and electro-fishing	*Not Mapped*
	Sand mining (in rivers)	Sand mines
	Limestone quarrying	*Not Mapped*
	Bauxite mining	Bauxite mines, limestone
Invasive species	Invasive animals	(*Cherax quadricarinatus*) Australian red claw
	Invasive plants	Bamboo
Habitat Destruction	Filling in and clearing of wetlands	*Not Mapped*
	Channelisation of natural rivers	*Not Mapped*

During the ecological integrity survey of academics and technicians, information was collected on the stresses affecting freshwater biodiversity. Table 6 illustrates the top threats as determined by these experts and the main actors that drive and regulate each threat.

Table 6: Main Actors driving the threats facing freshwater ecosystems in Jamaica

Threat	Main Actor(s)	Other Actors and Regulators
Nutrient Loading	**Small Farmers, large-scale**	**NEPA (Water Quality**

Threat	Main Actor(s)	Other Actors and Regulators
	farmers, Malfunctioning sewage plants, septic pit owners	Standards and Land-use planning) RADA, NWC
Invasive species	Aquaculture industry, ornamental fish industry, aquarium owners, fishers	Fisheries Division, Vetinary Division
Deforestation and removal of riparian vegetation	Small Farmers, large-scale farmers,	Forestry Department, RADA, Parish Councils
Unsustainable harvesting of freshwater biodiversity	Artisanal fishers	Fisheries Division, Pesticides Control Authority, NEPA (through the Wild Life Act)

2.5.2 Opportunities for conserving freshwater biodiversity

Although there are several threats facing freshwater biodiversity in Jamaica, there are also several opportunities for freshwater conservation. These opportunities are regarded as agencies and institutions, protected areas, conservation projects and other ongoing local and international programmes which are or can promote or facilitate the conservation of freshwater biodiversity. They are also critical in the development and implementation of effective strategies.

Table 7: Opportunities for conserving freshwater biodiversity in Jamaica.

Opportunity	Name	Description
Agencies	Water Resources Authority	Water Resources Master Plan for 2005 to 2025. WRA has allocated 60% of Jamaica's water resources to maintaining freshwater ecosystems.
	University of the West Indies	Freshwater research programme in Department of Life Sciences and Department of Geography and Geology conduct research relevant to the management of freshwater ecosystems.
	National Environment & Planning Agency	Biodiversity and Integrated Watershed and Coastal Zone Management Branches are responsible for implementing policies that protect freshwater biodiversity. The Protected area Branch is responsible for declaring and delegating the management of Pas.
	Fisheries Division	
	Forestry Department	

Opportunity	Name	Description
Non-Governmental Organisation	Jamaica Environment Trust	Specialised in environmental education and advocacy
Protected areas	Blue and John Crow Mountains National Park	
	Portland Bight Protected Area	
	Negril Environmental Protected Area	
	Mason River Reserve	
	Ramsar Designations: Black River and other areas	
Conservation Projects	Ridge to Reef/PALM and other USAID biodiversity initiatives	
	Integrated Watershed and Coastal Area Management	Regional Project implemented by CEHI , Buff Bay Pencar is the Jamaica pilot project area.
Programmes	Water for Life Decade (2005-2015) and other UN initiatives	
Other	Ecotourism efforts	Scenic waterfalls and rivers

2.6 Ecological Integrity

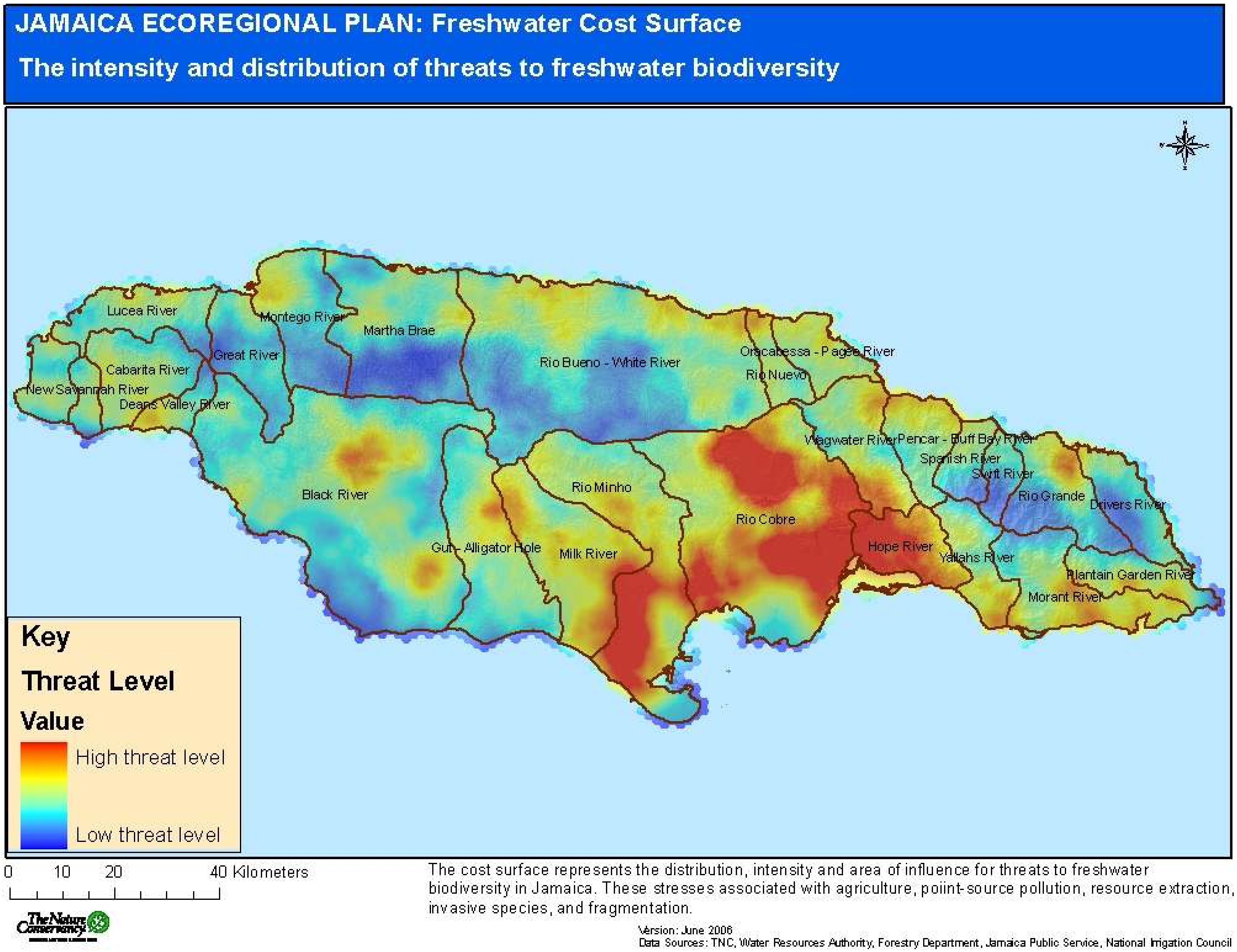
Conservation targets were screened to prioritise ecologically functional target occurrences for conservation efforts. A conservation target has integrity when all its key ecological attributes remain intact and function within their natural range of variation. Conservation targets with integrity are resistant to change in their structure and composition in the face of natural disturbances (eg. Fires, hurricanes and exotic species); and are resilient i.e. able to recover upon experiencing occasional disturbances (Ecological Systems Viability Workgroup Report, 2002).

Two methods of determining the ecological integrity of targets were attempted but only one method was eventually used. However they were both limited by insufficient islandwide data on the status of freshwater ecosystems and species. The first method involved an analysis of ecological integrity using expert questionnaires (Appendix 4). This yielded very little information on the actual status of target occurrences from the eight technical and academic respondents. However, information on the threats affecting targets and the watershed and systems known to the local conservation community was extracted.

The second approach to target-screening was a cost surface. The cost surface is a map of the sum impact of human activities on biodiversity across a landscape, often described as a *human footprint* (McPherson *et al* unpublished). The JERP freshwater cost surface (Map 6) represents the distribution, area of influence, and intensity of mapped threats to freshwater biodiversity. The concept of “cost” is useful because it assumes that in areas where the impact of human activities are severe, the cost of conservation will be higher than where impacts are mild or less severe.

The threats listed in Table 5 were used as the basis of the cost surface. Some of the threats (e.g. Filling in and clearing of wetlands and channelisation of natural rivers) were not mapped and were not used to construct the cost surface. The intensity and area of influence was determined for each threat as shown in Appendix 5. A GIS-based modelling tool (called a Human Actitivity Surface or HAS tool) was used to combine the distributions of threats across the island and synthesise their respective intensities and areas of influence into the cost surface.

According to the freshwater cost surface areas of dense settlement and intensive agriculture have the highest cost or risk for conservation purposes (in red) and those rural, more isolated and less densely populated areas have lower associated costs (in green and blue)



Map 6: Jamaica Cost Surface of threats to freshwater biodiversity

2.7 Protected Area Gap Assessment

The process of conservation area design was complimented by a protected area gap assessment. This gap assessment will inform the development of an ecologically representative networks of protected areas which is part of Jamaica's commitment under the Convention on Biodiversity (CoP 7). Although the JERP gap assessment preceded the National Gap assessment, the information generated through the JERP will feed into the national assessment.

The gap assessment was conducted to determine the effectiveness of the current protected area network in the conservation of freshwater biodiversity and to identify and recommend freshwater priorities for protection in a revised conservation area network. Three aspects of the Protected Area Network were analysed:

- **Representation**: indicates whether the target is represented and replicated sufficiently in the PA network.
- **Ecological Integrity**: indicates whether the represented targets are in adequate ecological condition and whether factors such as connectivity particularly for freshwater systems are incorporated in the network.
- **Management**: indicates whether the represented targets are protected in reality by the appropriate management systems.

The full Gap assessment results are presented in Appendix 7. The results indicated that Jamaica's current Protected Area Network does not protect any whole or functional freshwater ecosystems and must be refined and expanded to adequately protect freshwater biodiversity:

Target	Percentage of target protected
Eastern high altitude headwater streams	61.8%
Western freshwater wetlands	31.2%
Western ponds and lakes	18.7%
Eastern medium-sized streams	13.8%
western large rivers	10.9%
Western medium-sized streams streams	10.5%
Eastern springs	**7.3%**
Western coastal springs	**6.3%**
western springs	**6.2%**
Western freshwater caves	**5.6%**
Western karstic streams	**4.4%**
eastern coastal springs	**0.5%**
eastern large rivers	**0.0%**
eastern wetlands	**0.0%**
eastern ponds and lakes	**0.0%**
western_high altitude streams	**0.0%**
eastern freshwater caves	**0.0%**

KEY- % represented
>20%
10-20%
0-10%
no protection

IUCN BENCHMARK

CRITICAL FRESHWATER HABITATS

Figure 4: Representation of freshwater targets in Jamaica's PAs

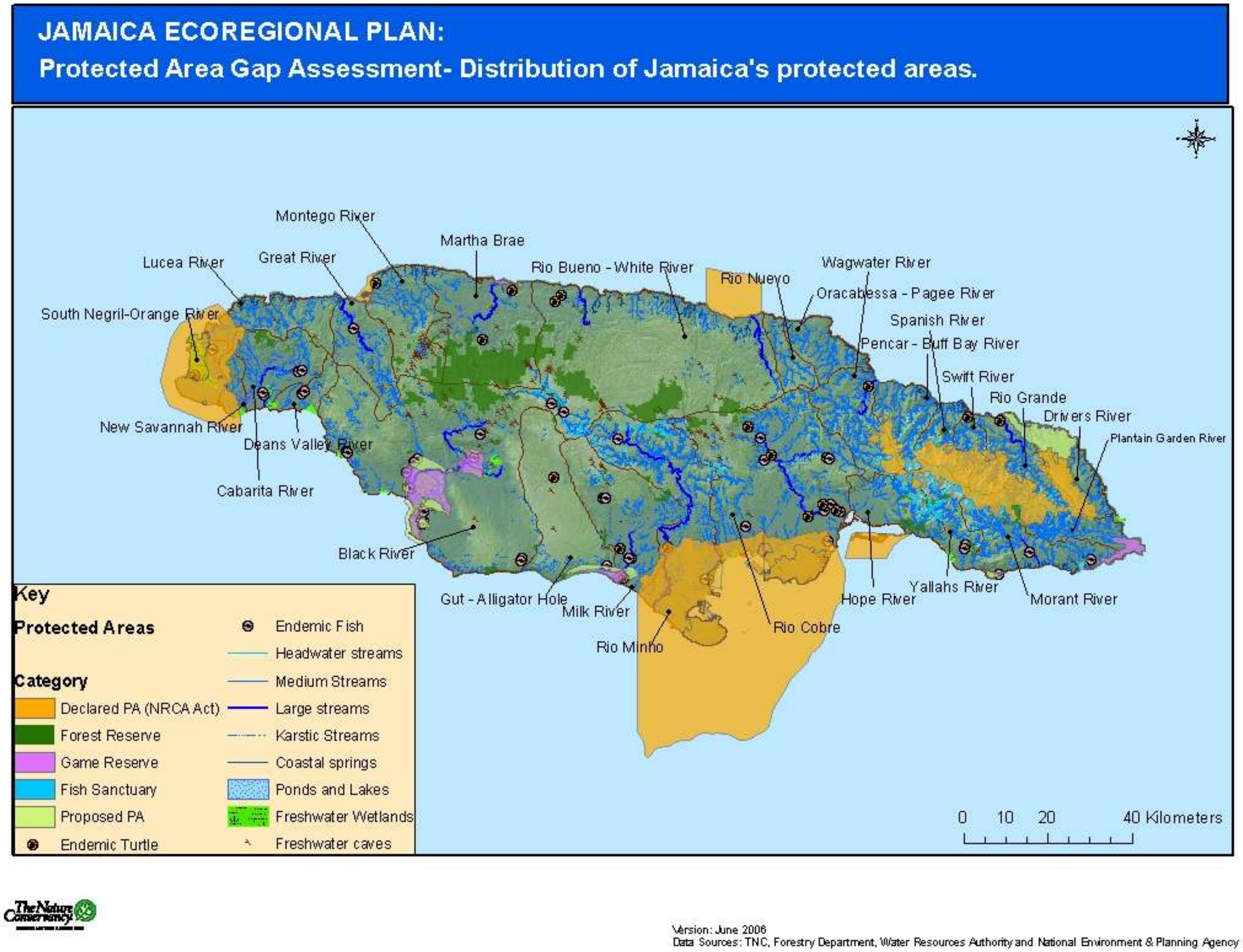
Representation Gaps (Figure 4 and Map 7)- Almost 50% of Jamaica's FW habitats are under or unrepresented in Jamaica's protected area network.

Major Gaps in Blue Mountains EDU:

- Blue Mountain large streams
- Blue Mountain lakes and ponds
- Blue Mountain freshwater wetlands
- Blue Mountain coastal streams

Major Gaps in Western limestone complex EDU:

- Western springs
- Western karstic streams
- Western coastal springs



Map 7: Overlay of Jamaica's protected areas and freshwater targets

Ecological Gaps: The current PA network fragments freshwater systems and does not preserve the longitudinal and lateral connectivity of freshwater ecosystems. The main ecological gap in the design of Jamaica's protected areas is that of connectivity, upstream and downstream reaches are not connected in the design of PAs.

Management Gaps: The existing Protected Area Network was not designed with freshwater biodiversity conservation in mind and so the PA Management does not explicitly manage or monitor freshwater ecosystems. This is a common situation around the world (Abell et al, 2007) and it should not be assumed that because a PA contains freshwater habitats, it is therefore protecting freshwater ecosystems.

Apart from Blue and John Crow Mountains National Park, management systems in Jamaica's protected areas have not incorporated freshwater biodiversity. In this assessment the distribution of freshwater ecosystems and of Jamaica's eight declared protected areas (i.e. those under the NRCA Act 1997) were compared using GIS to reveal the ecosystems that are unprotected or under-protected. A full examination of the management effectiveness of Jamaica's protected area network using the RAPPAM (Rapid Assessment and Prioritization of Protected Area Management) methodology is found in the Draft National Report on the Management Effectiveness Assessment and Capacity Development Plan for Jamaica's System of Protected Areas (Hayman, unpublished).

Table 8 : A summary of Jamaica's Protected Areas

Description	Total Area (Ha)	Number	Management status
National and Marine Parks, Environmental Protection Areas and Protected Areas declared under the NRCA Act	316,656	9	Managed by NEPA through delegations to Forestry Department, Urban Development Corporation and NGO's.
Forest Reserves declared under Forest Act 1996	99,881.27	166	Managed by the Forestry Department**
Game reserves declared under the Wild Life Protection Act	18,959 (provisional)	20	Managed by NEPA (off limits for hunting, wardens present to enforce no-hunting)
Fish sanctuaries declared under Fishing Industry Act		2	Managed by Fisheries Division
Proposed Protected Areas*** (as determined in the 1992 Protected Area System plan)		8	none

2.8 Freshwater Conservation Portfolio Development

Conservation areas were selected to efficiently achieve conservation goals for targets. According to Groves (2003), conservation areas are geographic areas of land and water specifically managed for the targets of biodiversity found within them. These include but are not limited to areas that are legally protected and encompass a wide spectrum of management schemes. Consequently, conservation areas include IUCN protected area categories as well as other conservation mechanisms such as easements, tribal reserves, community-managed and privately-owned parks. In the JERP analysis, conservation areas are have optimal occurrences of conservation targets combined with relatively low levels of human activity and collectively meet Jamaica's conservation goals. The full complement of conservation areas in an ecoregion is called a *portfolio*.

The freshwater portfolios are best described as the specific priority areas for implementing activities to conserve Jamaica's freshwater biodiversity. These portfolios were developed using decision-support software and a ranking system for watersheds based on explicit biological and socio-economic criteria.

Three portfolio scenarios were modelled:

1) Conservation portfolios without screening for ecological integrity- to determine where critical freshwater biodiversity areas would be if all systems were intact
2) Conservation portfolios with screening- to determine where critical freshwater biodiversity areas would be given present levels of degradation and human impacts.
3) Conservation portfolios with screening built upon present protected area network- to determine the most realistic arrangement of freshwater conservation areas given present levels of degradation and protected area network.

Three tools were used to develop conservation areas: GIS-based decision-support software 1) SPOT and 2) Marxan, and 3) a Watershed Prioritisation model.

- **SPOT and Marxan**: Both programmes cluster geographical units of analysis (in this case hexagons of 1km side) by way of an optimisation algorithm that minimises the total cost of a conservation network while selecting sites with the largest amount of conservation targets. The main inputs were the target distributions, cost surface and conservation goals.
- **Watershed prioritisation**: Watersheds were ranked according to their biological importance, ecological integrity, and conservation opportunities.

Two types of decision-support (spatial optimisation software) were used for preliminary portfolio analysis: 1) SPOT (Spatial Portfolio Optimisation Tool) developed by TNC for ecoregional planning and 2) Marxan version 1.8.6, an optimisation software developed for marine reserve system design. Both tools help to identify efficient portfolios of conservation areas by systematically choosing between the conservation targets located in candidate areas. Both tools were used to model freshwater conservation scenarios for the 10% and adaptive goals. However, SPOT was eventually preferred for analysis because its user friendly interface facilitated manipulation of inputs and modelling different scenarios. The methods used for generating the portfolios are summarised from their respective manuals.

In the absence of viability information on the targets, a cost surface for freshwater systems was generated as an into SPOT and Marxan analyses. The cost surface is a map of the sum impact of human activities on biodiversity and has the effect of screening out planning units with less healthy occurrences of freshwater targets. The cost surface was based on the distribution of threats, their intensity and their area of influence.

2.8.1 Watershed prioritisation portfolio

For this portfolio, watersheds were ranked in terms of their biological importance, ecological integrity and conservation opportunity (Table 9). The calculations are provided in Appendix 8 and a summary of rankings is presented in Table 10

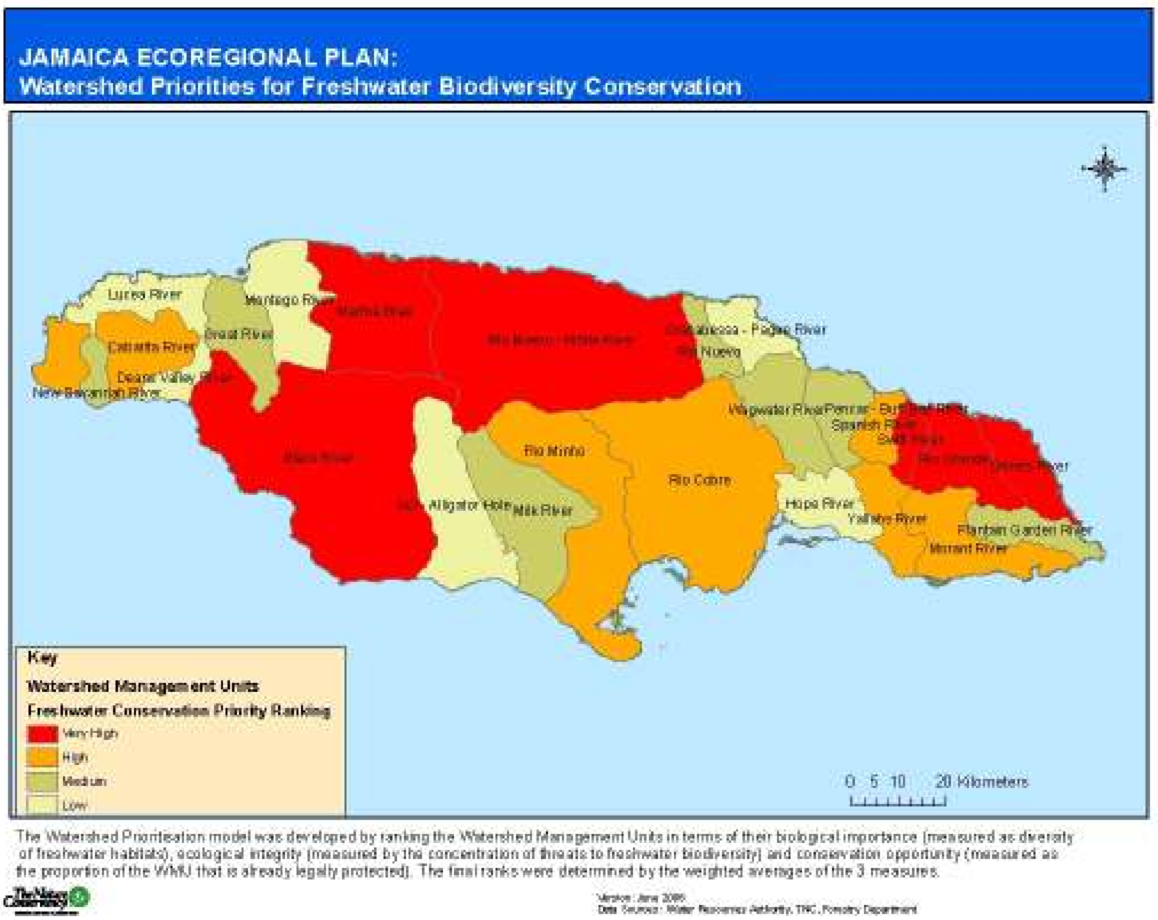
Table 9: Criteria for the watershed prioritisation model

CRITERIA	MEASURES
Biological importance (High, Low, Medium)	Habitat diversity, Species Richness
Ecological integrity (Intact, Altered, Degraded)	Natural Land-cover (%), Agriculture (%), Urban cover (%), Sewage/Industrial outfalls, Population Density/ Pit Latrine, Water Abstraction Intensity (Amt extracted/amount available), Impoundments
Conservation opportunity (High, Medium, Low)	Proportion of watershed in declared protected areas (%), Proportion of watershed in forest reserves (%), Proportion of watershed in proposed protected areas (%)

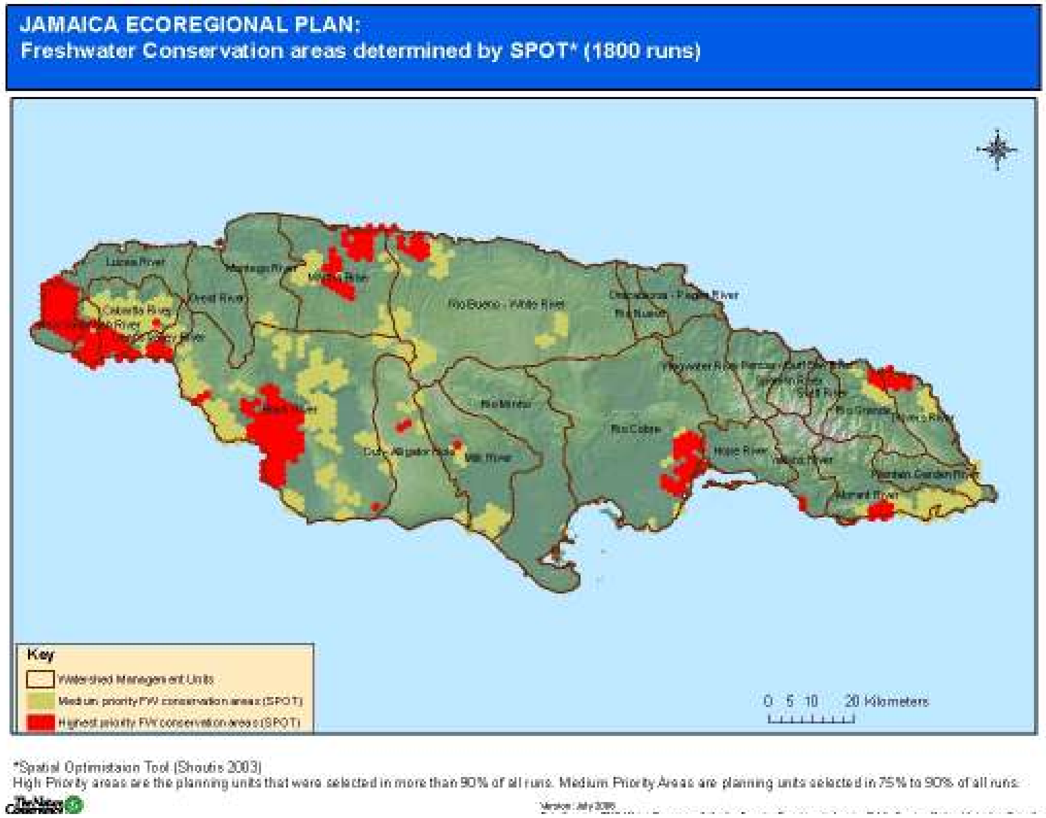
Table 10: Watershed prioritisation model scores and watershed ranks in support of conservation area design

EDU	WMU name	Biological rank	Ecological integrity rank	Conservation Opportunity rank	Final Rank
Blue Mountain	*Rio Grande*	*5.00*	*3.00*	*1.0*	*1.00*
	Drivers River	*4.00*	*4.00*	*4.0*	*2.00*
	Swift River	*7.00*	*1.00*	*3.0*	*3.00*
	Yallahs River	*1.00*	*8.00*	*7.0*	*4.00*
	Spanish River	*8.00*	*2.00*	*2.0*	*5.00*
	Morant River	*3.00*	*10.00*	*6.0*	*6.00*
	Wagwater River	2.00	11.00	8.0	7.00
	Pencar - Buff Bay River	11.00	5.00	8.0	8.00
	Rio Nuevo	9.00	7.00	10.0	9.00
	Plantain Garden	12.00	6.00	5.0	10.00
	Hope River	6.00	12.00	9.0	11.00
	Oracabessa - Pagee River	10.00	9.00	10.0	12.00
Western Limestone	*Black River*	*2.00*	*6.00*	*10.0*	*1.00*
	Martha Brae	*8.00*	*1.00*	*4.0*	*2.00*
	Rio Bueno-White River	*4.00*	*5.00*	*7.0*	*3.00*
	South Negril-Orange River	*7.00*	*4.00*	*1.0*	*4.00*

EDU	WMU name	Biological rank	Ecological integrity rank	Conservation Opportunity rank	Final Rank
	Rio Cobre	*1.00*	*13.00*	*5.0*	*5.00*
	Rio Minho	*3.00*	*12.00*	*3.0*	*6.00*
	Cabarita	*6.00*	*8.00*	*9.0*	*7.00*
	Great River	10.00	3.00	12.0	8.00
	New Savannah	14.00	2.00	2.0	9.00
	Milk River	5.00	14.00	10.0	10.00
	Montego River	11.00	9.00	8.0	11.00
	Gut-Alligator Hole	12.00	7.00	11.0	12.00
	Deans Valley River	9.00	11.00	12.0	13.00
	Lucea River	13.00	10.00	6.0	14.00



Map 8: Map of priority watershed for conservation based on the watershed prioritisation model



Map 9: High and medium priority freshwater portfolio sites selected by SPOT

2.8.2 SPOT and Marxan freshwater portfolios

Both SPOT and Marxan were used for the computer-based modelling. However, they generated different outputs even when the same parameters were used. Eventually, SPOT was preferred because the resulting portfolios were less fragmented, and because of its user-friendly interface in ArcView 3.3. The main inputs for the SPOT runs were the GIS target layers, the cost surface and the target goals. SPOT analyses a region by dividing the area into small parcels called analysis units (planning units in Marxan). The software forms a portfolio of conservation areas by marking analysis units within the region as included or excluded from the portfolio (Shoutis, 2003). During SPOT runs, millions of portfolios are formed and analysed according to the following criteria:

- How well the conservation goals are met.
- Total area of the portfolio.
- The fragmentation of the portfolio.

The portfolio that is most efficient, i.e. does the best job of meeting the conservation goals, while minimising the area and degree of fragmentation of the portfolio, is output as the final result. Conservation areas selected by SPOT are shown in Map 9. The layout of these conservation areas does not preserve the longitudinal connectivity of fluvial systems. It was therefore necessary to adjust the SPOT portfolio in order to reflect the requirements of freshwater ecosystems.

2.8.3 Integrating SPOT and watershed prioritisation models

The resulting conservation areas encompass areas selected by SPOT and Marxan models which occurred in priority watersheds. Socio-economic and political considerations were incorporated by way of the cost surface and the inclusion of threats and human activities in watershed prioritisation.

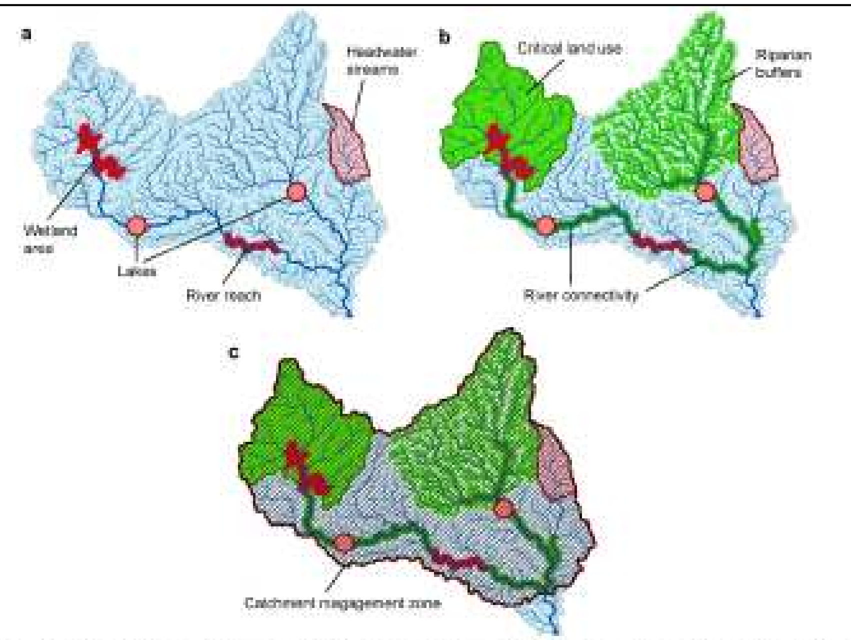


Fig. 1 – Schematics of proposed freshwater protected area zones. (a) Freshwater focal areas, such as particular river reaches, lakes, headwater streams, or wetlands supporting focal species, populations, or communities. (b) Critical management zones, like river reaches connecting key habitats or upstream riparian areas, whose integrity will be essential to the function of freshwater focal areas. (c) A catchment management zone, covering the entire catchment upstream of the most downstream freshwater focal area or critical management zone, and within which integrated catchment management principles would be applied.

Figure 5: Proposed freshwater protected area designs from Abell et al (2007)

A catchment approach was used in the design of freshwater conservation areas. This approach identifies entire stream networks as the unit of conservation and incorporates the upstream-downstream and land-water connections that maintain freshwater ecosystems (Abell et al 2007) and as outlined in Saunders, Meeuwig and Vincent (2002). Freshwater conservation areas are therefore delineated as river/stream reaches or (sub) watersheds, the contributing areas to springs, lakes, ponds, caves, and wetlands.

The resulting conservation areas were drawn manually and were based upon buffered stream reaches, and existing protected areas in priority watersheds. Streams were buffered as follows:

1) 1-3 order streams- 1000m
2) 4-6 order streams 100m

3) >6order and karstic streams- 50m, and
4) coastal springs and streams 25m

2.9 Freshwater Conservation Strategies

Conservation strategies are activities that either abate the threats to or restore and maintain the ecological integrity of conservation targets. Ideally conservation strategies in ecoregional plans are effective over multiple areas and are prioritised according to 1)how well they protect biodiversity in all three realms (freshwater, terrestrial and marine), 2) feasibility and 3) urgency of action (as in the case with severe threats or narrow windows of opportunity for action). JERP conservation strategies were explicitly linked with the findings of the Protected Area Gap Assessment, Threats and Opportunity Assessment, and will be focussed as much as possible on conservation areas.

Table 11: Main JERP freshwater findings and conservation objectives

Ecoregional findings	Conservation Objective
Most freshwater habitats are under or completely unprotected in Jamaica's Protected Area Network	1a) Include un-protected freshwater systems in Protected Area Network across at least 10% of their distribution
Jamaica's Protected Area network does not preserve the connectivity of freshwater ecosystems	1b) Redesign established Protected Areas using a watershed approach to restore lateral and longitudinal connectivity in freshwater ecosystems.
Management effectiveness of existing Protected Area Network with respect to freshwater systems is uncertain.	1c) Assess and improve the management effectiveness of protected areas with respect to freshwater ecosystems.
Top threats on islandwide scale are nutrient loading, deforestation and removal of riverside vegetation, and invasive species.	2a) Mitigate or reduce main threats to freshwater ecosystems on an islandwide scale.
	2b) Mitigate or reduce main threats to freshwater ecosystems in critical conservation areas.
Significant opportunities to advance freshwater conservation, such as protected areas, Ridge-to-Reef initiatives, environmental education and environmental funding are currently under-utilised.	2c) Incorporate freshwater biodiversity conservation actions into significant existing protected areas, projects and other initiatives.

Ecoregional findings	Conservation Objective
Riparian forests are the most degraded or extirpated freshwater community	3) Restore degraded freshwater ecosystems in critical areas
Huge Information Gaps on Freshwater biodiversity. Up to date information on freshwater biological systems, practitioners and projects generally absent. Many watersheds and freshwater ecosystems un or under-researched.	4a) Fill priority ecological and geographical information gaps 4b) Strengthen freshwater conservation network by creating opportunities for information exchange.
Insufficient local capacity to assess, plan and implement freshwater biodiversity conservation	5) Build local capacity in freshwater biodiversity conservation.

2.10 Data and Process gaps Assessment

2.10.1 Ecological and Socio-Economic Data Gaps

The main ecological gap was the absence of information on aquatic species level targets and their distribution. The experts consulted were also unable to suggest fine-filter species. Distribution information on the island's endemic vertebrates (fish and turtle) were obtained from Caldwell, D. K. (1966) and from Lee, *et al* (1983). However, all other distribution data were unavailable. Critical data needs include information on migratory fish and crustaceans, subterranean species such as *Troglocubanus jamaicensis* and *Sesarma verlyii* and other endemic or threatened invertebrates.

Another ecological gap was information on special aquatic ecosystems, for example, there was no information on riparian communities and many of these have already been removed for settlement, transport and agriculture. Large streams were mapped as lines when they may in fact be transition zones between terrestrial and aquatic communities including the main channel and it riparian community. It is also unknown whether these zones still exist since they often coincide with areas of human settlement.

The threat status of many human activities was also unknown for example the effects of harvesting freshwater species such as bussu (*Neritina punctulata*), shrimp poisoning in Portland streams and the impacts of introduced aquatic species. Furthermore, there is no information on the effects of dams on Jamaican aquatic fauna, although studies from similar ecosystems in Puerto Rico and Costa Rica indicate that moderate to severe negative effects depending on the height and operation of the dam (Holmquist *et al* 1998).

2.10.2 Planning process gaps

The main gap in the freshwater ERP was the absence of an adequate analysis of the health and integrity of freshwater ecosystems and species. As such, threats information was used as an indicator of the integrity of the biological systems (for example rivers in deforested areas were assumed to be less healthy than those in forested areas). This indirect measurement of the status of freshwater in the island is reasonable given the limited data available, however it helps to underscore the fact that an island-wide assessment of prioritised freshwater communities and species and a comprehensive seamless database of freshwater ecosystem information, incorporating water quality and biological information are necessary.

2.10.3 Recommendations for improving the process of the next JERP

The following are recommendations for streamlining and enhancing the next iteration of the JERP:

- Verify target distribution and status through ground-truthing and IKONOS satellite imagery
- Complete a freshwater information database (linked to and compatible with existing databases such as the water quality database at WRA and the Jamaican Caves Organisation database) before starting a new ERP iteration.
- The JERP should be the responsibility of dedicated staff. This iteration of the JERP freshwater assessment was delayed because there was at best 50% of the time of one full-time employee working on it.
- Assemble a trained core team of ecologists, GIS technicians and conservation planners to guide the ERP process before planning commences.

3.0 Vision for Freshwater Biodiversity Conservation in Jamaica

This freshwater assessment is geared towards the effective conservation of Jamaica's freshwater ecosystems. Jamaica's freshwater ecosystems are unique and vital to the life and livelihood of Jamaicans. *Effective Conservation* envisions that there will be places where species, natural communities, and ecosystems are viable, threats are adequately mitigated, abated or prevented, and the conservation management status is adequate to ensure the long-term persistence of biodiversity.

The vision for Jamaica's freshwater biodiversity takes this into account:

- Healthy freshwater ecosystems with the best streams, wetlands, freshwater caves and ponds actively managed with the assistance of skilled and dedicated corps of ecosystem managers in a context where the connection between freshwater ecosystems and human well-being is highly valued

The main conservation initiative is summarised as follows:

> *TNC and partners will protect natural aquatic ecosystems in Jamaica's main freshwater conservation areas by conserving and managing representative rivers, wetlands, ponds and cave systems within an effective protected area network. These conservation efforts will be bolstered by TNC's support for targeted freshwater research, appropriate policy changes and a communication and education programme directed at all levels of decision-makers and resource users.*

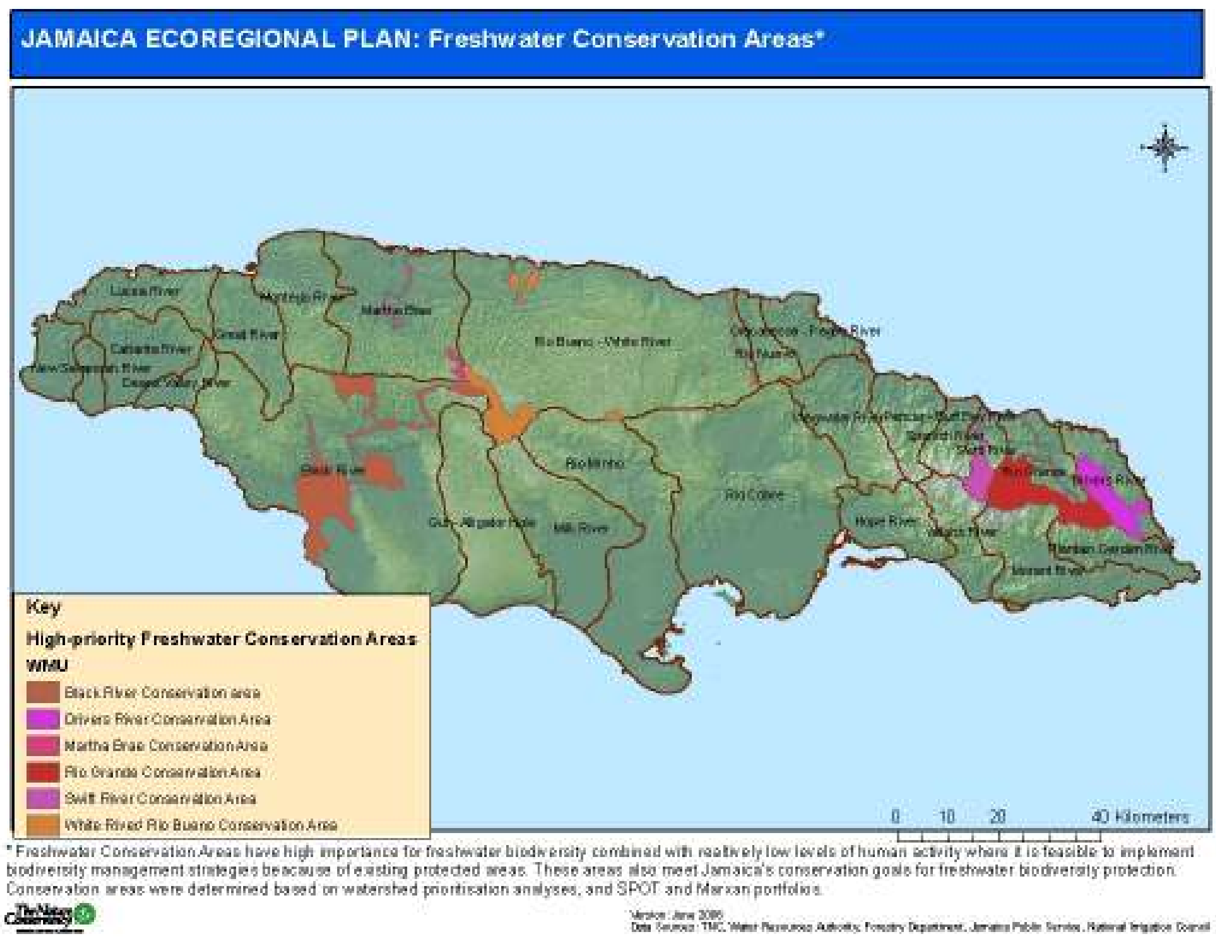
3.1 Freshwater Conservation Areas

The top freshwater Conservation areas are listed in Table 12 and illustrated in Map 10. The High Priority areas collectively meet JERP conservation goals and Jamaica's CBD obligations

Table 12: Jamaica's High and Medium freshwater conservation areas

Priority	Conservation Area	DESCRIPTION
High Priority (Together these areas meet the 10% conservation goal and ecologically significant goals)	Black River	This includes the Black River main-stem, Upper and Lower Morasses, wetlands, coastal springs, and the freshwater lake in South-central St. Elizabeth
	Cockpit/Martha Brae	Includes Cockpit Country karstic systems, upper Martha Brae watershed and river main-stem, and Falmouth wetlands.
	Northeast Portland	Includes upper Rio Grande and Drivers River watersheds Rio Grande main-stem and coastal springs and wetlands in Drivers River.

Priority	Conservation Area	DESCRIPTION
	Rio Bueno/White River	Upper Rio Bueno watershed, Rio Bueno main-stem and coastal springs, upland wetlands and ponds in White River watershed.
Medium Priority	Swift River	Upper Swift River Watershed, Swift River main-stem and coastal springs.
	Portland Bight	Lower Rio Cobre and Lower Rio Minho watersheds.
	Negril	Coastal Negril, Negril Morass and Fish River Hills
	Upper Cabarita/ Dolphin Head	Includes Upper Cabarita watershed and Cabarita main-stem.



Map 10: Jamaica's High Priority Freshwater Conservation Areas

3.2 Freshwater Conservation strategies

Table 13: Summarised JERP freshwater conservation strategies	
1. Policy-based actions	*Improve policy framework for conservation and develop management and restoration plans for priority conservation areas:*
1.1. Policy	1. Support inclusion of inland fisheries and completion of new draft Fisheries Policy and Fishing Bill for Cabinet review and legislation. 2. Revise Protected Area Policy to reflect JERP recommendations such as: ▪ Designating and protecting entire river corridors. ▪ developing existing and future mechanisms for protecting freshwater ecosystems (rivers, ponds and caves), on private lands for example. ▪ incorporating high-priority conservation areas identified within JERP 3. Develop policies for community-based management of freshwater ecosystems in critical areas outside of established Protected Areas. 4. Develop a National Freshwater Policy and Plan.
1.2. Management plans	1. Rio Grande Management Plan 2. Black River and/or Martha Brae Management Plan
1.3. Legislation	1. Develop mechanisms for conservation on private lands e.g. regulations under Watershed Protection Act and promote enactment of draft regulations relating to conservation easements. 2. Support legislation to prevent new introductions of invasive species
2. Communication and Education-	*Improve technical capacity and public awareness in support of freshwater conservation*
2.1. Formal education	1. Train students in freshwater conservation methods through internships, short courses and volunteer programme.
2.2. Awareness	1. Design and implement a public awareness campaign promoting freshwater conservation and the importance of freshwater ecosystems to Jamaica's society and economy targeting the main players in environmental management and education, funding, conservation and development sectors. 2. Develop and disseminate public education materials (including school curriculum items) on the importance of freshwater ecosystems to Jamaica's society and economy and their status.
2.3. Capacity-building/	1. Train water resource management and protected area

Training	practitioners in freshwater conservation methods (planning, implementation and monitoring).
2.4. Other	1. Initiate regular TNC-hosted Caribbean basin-wide conferences/symposia on freshwater biodiversity and conservation
3. Research actions	*In collaboration with the University of the West Indies, design an applied National Biodiversity Research framework which will underpin and inform Jamaica's biodiversity conservation and management strategies and address important conservation gaps (species, communities, important ecological phenomena)*
3.1 FRESHWATER	Primary Freshwater research areas: a. Biology, distribution and status of Jamaica's endemic and migratory freshwater species and riparian communities b. Population dynamics, sustainability and management requirements for economically and nutritionally important freshwater species; e.g. freshwater shrimp, mullets and other freshwater fish. c. Status and distribution of invasive species that harm freshwater systems. d. Compile freshwater database of existing ecological and geographical data on freshwater biological systems in Jamaica. e. Contribution of ecological products and services provided by freshwater ecosystems to Jamaica's society and economy particularly in priority freshwater conservation areas.
3.2 CROSS-CUTTING RESEARCH PRIORITIES	f. Research ecological processes (e.g. migration) and connectivity as a basis for refining and revising protected area boundaries g. Explore diversification of fishing practices and selective fishing activities towards reducing fishing pressure at important inland fishery sites (Black River, Rio Grande and others)
4. Conservation Area Management	*Promote protected areas as ecologically functional land and sea-scapes and as a platform for managing and rehabilitating representative freshwater ecosystems.*
4.1.Functional Land /Seascapes	1. Append lower Rio Grande/ Drivers River to wider Blue and John Crow Mountains Protected Area to create a functional protected area with upstream-downstream connectivity. 2. Protect from Cockpit Country north into downstream Martha Brae watershed and/or south into Black River watershed to create a functional protected area with upstream-downstream connectivity. 3. Improve watershed management in 1-2 priority watersheds (e.g. Rio Grande, Black River, Martha Brae or Drivers River) to demonstrate practical approaches to integrated freshwater,

	terrestrial and coastal ecosystem management.
4.2. Monitoring	1. Develop monitoring networks and protocol to provide current islandwide information on the status of freshwater ecosystems
4.3. Restoration	1. Control/eradicate invasive species (e.g. *Cherax,* Bamboo), prevent new introductions and restore native species in critical areas such as Black River watershed. 2. Reduce over-harvesting and river-poisoning in Rio Grande watershed through participatory community-based initiatives.. 3. Reduce nutrient levels in the following critical conservation areas: a. Upper Martha Brae watershed: by piloting and promoting appropriate sewage disposal technology. b. Black River and lower Martha Brae watersheds: through working with agribusiness interests (sugar cane, and aquaculture) to implement appropriate waste-water technology and systems. 4. Restore riparian zones with native species in critical areas: Rio Grande, Black River and Martha Brae.
4.5. Protected areas	1. Build technical and management capacity to manage freshwater ecosystems within PAs through a pooled expert base within the Jamaica Protected Areas Trust (JPAT).
4.5. Community-based initiatives	1. Support community-based management of inland fisheries (and other resources) in Rio Grande and Black River.
5.Enforcement and Compliance	*Strengthen existing structures to ensure compliance with environmental statutes in support of freshwater conservation particularly in freshwater conservation areas.*
	1. Support the Fisheries Division in training and placing River wardens in priority freshwater conservation areas. 2. Support stakeholders' compliance with water quality standards in critical conservation areas such as Black River.
6. Conservation Funding	Raise funding and in-kind contributions to support priority conservation strategies.
	1. Devise long-term sustainable financing strategies specifically targeting PAs through JPAT 2. Mobilise funding for priority freshwater conservation actions as part of the JERP.

3.3 Measures of Success

The main objective of this freshwater analysis is to determine priorities for the conserving Jamaica's freshwater biodiversity. These JERP recommendations have been made based on the available information and guided by expert opinion. However, such knowledge is continually upgraded through research and improved data processing techniques.

The JERP is therefore not a rigid set of conservation strategies and goals. On the contrary, it is expected that the areas and strategies identified in this document will be regularly evaluated and adjusted to ensure effective conservation. The topic of measuring the success of ecoregional conservation is currently receiving much attention from conservation practitioners. It is expected that the science and practice of ecoregional measures will be tested and developed in the coming years. Three groups of measures have been proposed:

- Measures of Biodiversity Status
- Measures of Threat Status
- Measures of Conservation Management Status

Two simple freshwater measures have been determined for this first iteration of the JERP:

1. Percentage protection of freshwater habitats- This uses an indicator developed in the PA Gap assessment and will track the management status of freshwater targets.
2. Number of freshwater conservation projects implemented- This indicator measures the implementation of the JERP and the progress towards the main objective through policy and other means.

It is recommended that these measures are tracked and updated by TNC-J every five years.

4.0 Summary and Recommendations

The Jamaican economy and society depend heavily on freshwater ecosystems for water, food and recreation among many other goods and services. However, freshwater conservation has been a major gap in the country's conservation agenda until now. This JERP is considerable value-added to previous plans (such as the Biodiversity Strategy and Action Plan) because it integrates science-based recommendations for the sustainability of Jamaica's freshwater ecosystems and the biodiversity therein.

The main products of the Jamaica Ecoregional Plan are as follows:

1. Framework and methodology for integrated biodiversity conservation planning in Jamaica as detailed in this full ecoregional report.
2. GIS database of freshwater, marine and terrestrial biodiversity and socio-economic factors (http://maps.cathalac.org/website/tncmaps/tncmain.html).
3. Recommended and prioritized conservation areas and actions for Jamaica's biodiversity (as detailed in this full ecoregional report).

Following the JERP, the next steps will be to implement the most critical management strategies and improve the data used to inform freshwater conservation. Management activities will be initiated in the highest priority conservation areas according to the strategies outlined above. Another priority is measuring the impact and implementation of this plan using indicators such as protected area gaps and progress towards CBD goals as they pertain to freshwater biodiversity.

Finally we hope that this Jamaica Ecoregional Plan will guide comprehensive, effective, highly-leveraged and long lasting conservation in Jamaica. We cannot accomplish this task alone, and hope to work closely with conservation partners and stakeholders to implement the plan and achieve long-awaited conservation success.

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Acronyms

AES	Aquatic Ecological System
BJCMNP	Blue and John Crow Mountains National Park
CBD	Convention on Biological Diversity
CCAM	Caribbean Coastal Area Management
CERP	Caribbean Ecoregional Plan
CEHI	Caribbean Environmental Health Institute
CHM	Clearing House Mechanism
CITES	Convention for International Trade of Endangered Species
COP	Conference of Parties
DOC	Department of Chemistry
DOLS	Department of Life Sciences
DOGG	Department of Geology and Geography
EDU	Ecological Drainage Unit
EFJ	Environmental Foundation of Jamaica
FD	Forestry Department
GIS	Geographic Information System
GoJ	Government of Jamaica
IOJ	Institute of Jamaica
ISCF	Island Special Constabulary Force
IUCN	World Conservation Union
JCDT	Jamaica Conservation and Development Trust
JDF	Jamaica Defense Force
JEAN	Jamaica Environmental Advocacy Network

JERP	Jamaica Ecoregional Planning Project/ Jamaica Ecoregional Plan
JNHT	Jamaica National Heritage Trust
JNPTF	Jamaica National Parks Trust Fund
JPAT	Jamaica Protected Area Trust
MLGE	Ministry of Local Government and Environment
NBSAP	National Biodiversity Strategy and Action Plan
NCRPS	Negril Coral Reef Preservation Society
NEPA	National Environment and Planning Agency
NEPT	Negril Area Environmental Protection Trust
NFMCP	National Forest Management and Conservation Plan
NGO	Non-governmental Organization
NISP	National Implementation Support Programme
NLA	National Land Agency
NRCA	Natural Resources Conservation Authority
NWC	National Water Commission
PA	Protected Area
PASP	Protected Area System Plan
POW	Programme of Work
RADA	Rural Agricultural Development Agency
RAPPAM	Rapid Assessment and Prioritization of Protected Area Management
TNC	The Nature Conservancy
TPDCo.	Tourism Product Development Company
UDC	Urban Development Corporation
UNEP	United Nations Environment Programme

USAID	United States Agency for International Development
UWI	University of the West Indies
WLPA	Wild Life Protection Act
WRA	Water Resources Authority
WWF	World Wildlife Fund

Appendices

Appendix 1: Data Sources and Data Processing

Data Sources for Conservation targets

Target/ Threat	Data Source	Data layer	Comments
TARGETS			
Small high altitude streams	WRA, TNC		
Med-sized, low altitude streams	WRA		
Large, low-altitude streams	WRA		
Small coastal springs and streams	WRA		Short streams flowing on limestone or coastal aquiclude and originating within 5km of the coast.
Freshwater wetlands	Forestry Department	Landuse 1998 (Swamp, Herbaceous wetland, Semi-permanently flooded grassland, Seasonally/temporarily flooded grassland and swamp forest)	This was later edited by excluding areas that were shown as mangroves on IKONOS imagery.
Permanent and ephemeral ponds	Forestry Department	Landuse 1998 (water)	Marine areas and artefacts such as bauxite processing and irrigation ponds were excluded.
Springs	WRA		
Freshwater caves	WRA		Freshwater caves are caves known to have freshwater systems and were derived from the WRA Jamaica cave layer. These include the following categories: Blocked Sink, Blue Hole, Cave with a pool, Caves with pools, Choked sink, Complex river passage, Complex

Target/ Threat	**Data Source**	**Data layer**	**Comments**
			stream cave, Impenetrable sink, Impenetrable rising(s), Labyrinth-stream passage, Resurgence, Resurgence caves, River cave, River passage, River sink, River Passage, Shaft to a pool, Shaft to water, Spring, Stream Labyrinth, Stream (P)passage, Sumped Sink, Sumped streamway, Sumped rising, Wet passage.
Small, high altitude non-karstic streams	WRA		
Karstic aquatic systems- *freshwater caves, springs and karstic streams*	WRA		
Med-sized, low altitude, non karstic, streams	WRA		
Endemic Fish: *Gambusia melapleura, Gambusia wrayi, Limia melanogaster, Cubanichthys pengelleyi.*	TNC	Hand digitised based on Lee, et al.(1983) Caldwell, (1966)	
Endemic turtle: *Pseudemys terrapen*	TNC	Hand digitised based on Schwartz, et al (1991).	
THREATS			
Banana and sugar cane plantations, Small scale agriculture and grasslands, Tree crops (coffee, citrus) and agro-	Forestry/TNC land use map		

Target/ Threat	Data Source	Data layer	Comments
forestry			
Processing plants, mud lakes	Forestry/TNC land use map		
Sewage contamination from sewage plant outfalls	WRA		
Sewage contamination from latrines	TNC	STATIN survey of living conditions 2001 and Electoral Districts	
Industrial waste outfalls	WRA		
Urban areas			
Hydro-electric, irrigation and water storage dams	National Irrigation Commision, Jamaica Public Service, National Water Commision		
Surface Diversion, water use in drainage basins	WRA		
Sand mines	Mines and Geology Division		
Bauxite mines, limestone	Forestry Department		
Cherax quadricarinatus) Australian red claw	Department of Life Sciences (Sacha-Renee Todd and Eric Hyslop)		
Bamboo	Forestry Department		

Data Processing

AES targets were mapped in Arc View 3.3 and using several methods to generate features from already existing data. Streams were initially mapped using RiverTools 2.4. RiverTools 2.4 (www.rivix.com) is a software application for digital terrain and river network analysis. It was used to extract drainage network patterns and other hydrologic data from the DEM of Jamaica. The DEM was generated for the island by TNC GIS personnel from 1998 Landsat imagery.

Although RiverTools created a comprehensive database of the Jamaica's hydrography- including watershed boundaries, drainage network, and stream class-there were several drawbacks that limited its use in the Jamaica ERP. In karstic areas which account for two-thirds of the Jamaican landscape, much of the drainage is subterranean. However, RiverTools generated artefact stream systems based on topography, in areas where no streams existed. In flat areas such as the Black River Morasses, the lack of differences in elevation forced RiverTools to generate a series of straight lines toward sea level (discussed in Chapter 2). It was therefore necessary to supplement the RiverTools maps with the hydrology layers from NEPA and WRA to produce more accurate GIS layers for fluvial targets. Lakes and ponds were extracted from NEPA hydrology layer and the FD 1998 land use map. Wetlands were mapped from the FD 1998 land use map. The following land uses were amalgamated in the wetlands layer, Swamp, Herbaceous wetland, Semi-permanently flooded grassland, Seasonally/temporarily flooded grassland. Digitised and georeferenced topographical sheets for the island of Jamaica were used to verify the systems target layers.

APPENDIX 2: Conservation target Descriptions and Key Ecological Attributes

Freshwater Conservation Target Descriptions

	EDU	Freshwater target	Descriptive details
1	Blue Mountains	**AES #1.1- Small high altitude streams**	**Hydrology**: 1st to 3rd order streams **Geology**: Volcanic/metamorphic **Elevation**: >600m above sea level **Other Comments**: Special habitat type, may have rare species, Important for functioning of FW habitats in Blue Mountains; *eg. Headwaters of Blue Mountain streams Rio Grande, Yallahs, Wag Water*
2	Blue Mountains	**AES #1.2- Med-sized, low altitude streams**	**Hydrology**: 4th to 6th order streams **Geology**: Volcanic/metamorphic **Elevation**: <600m above sea level **Other Comments**: High Biodiversity, Good representative of FW systems in Blue Mountains, Important for functioning of FW habitats in Blue Mountains; *, eg.Middle reaches of Blue Mountain stream; Swift River, and low altitude tributaries in Rio Grande Basin*
3	Blue Mountains	**AES #1.3- Large, low-altitude streams**	**Hydrology**: > 6th order streams **Geology**: Volcanic/ metamorphic **Elevation**: , <600 m above sea level **Other Comments**: High Biodiversity, special habitat type, Functionally important for diadromous species and others with marine/estuarine phases; *eg. Lower reaches of Blue Mountain stream Rio Grande, Yallahs, Wag Water*
4	Blue Mountains	**AES #1.4-Small coastal springs and streams**	**Hydrology**: 1st to 3rd order streams **Geology**: Coastal aquiclude limestones, elevated reefs **Elevation**: coastal, <600 m above sea level **Other Comments**: Special habitat type, Functionally important for anadromous species and others with marine/estuarine phases; *eg. Springs at Frenchman's cove, Fum Fum Spring in Buff Bay watershed*
5	Blue Mountains	**AES #1.6- Freshwater wetlands**	**Hydrology**: Wetlands (Semi-permanently flooded evergreen sclerophyllous forest, Seasonally/ temporally flooded grassland, Seasonally/ temporally flooded forb vegetation, Semi-permanently flooded grassland) **Geology**: Volcanic/ metamorphic/ derived alluvium **Elevation**: <600 m asl **Other Comments**: High biodiversity, special habitat type, functionally important for many FW species; *eg. Annatto Bay wetlands, The great morass in St. Thomas*
6	Blue Mountains	**AES #1.7- Permanent and ephemeral ponds**	**Hydrology**: permanent and ephemeral ponds **Geology**: Volcanic/ metamorphic derived alluvium **Elevation**: <600 m asl **Other Comments**: Special habitat type (lakes & ponds), high biodiversity, possibly rare species; *eg Nine Miles Pond in St. Thomas*
7	Western Limestone Complex	**AES #2.1- Small, high altitude non-karstic streams**	**Hydrology**: 1st to 3rd order streams **Geology**: Central Inlier , yellow limestones and clastics **Elevation**: >600m **Other Comments**: Small, cool streams overlying the Central Inliers (yellow limestone and clastics). May be a centre of aquatic endemism in Jamaica; *eg. Headwaters of Rio Minho and Black River*

	EDU	Freshwater target	Descriptive details
8	Western Limestone Complex	**AES #2.2 Large low altitude streams** (Alluvial, coastal influenced rivers,)	**Hydrology**: > 6th order **Geology**: Alluvial **Elevation**: <600m above sea level **Other Comments**: High Biodiversity, Important for functioning of FW habitats in Western Limestone Complex; *eg. Martha Brae, Rio Minho, Rio Cobre, Great River*
9	Western Limestone Complex	**AES #2.3a- Karstic aquatic systems: freshwater caves**	**Hydrology**: aquatic subterranean pools, streams and seeps **Geology**: karstic white limestone **Elevation**: variable **Other Comments**: Special habitat type, subterranean habitats may have endemic or rare species; *eg. Coffee River Cave, Black River Blue Hole,*
10	Western Limestone Complex	**AES #2.3b- Karstic aquatic systems: karstic streams**	**Hydrology**: karstic surface streams **Geology**: karstic white limestone **Elevation**: variable **Other Comments**: Special habitat type, eg. *Martha Brae Springs*
11	Western Limestone Complex	**AES #2.3c- Karstic aquatic systems: springs**	**Hydrology**: karstic springs including blueholes, **Geology**: karstic white limestone **Elevation**: variable **Other Comments**: Special habitat type, eg. *Martha Brae Springs*
12	Western Limestone Complex	**AES #2.4-Small coastal springs and streams**	**Hydrology**: 1st to 3rd order streams **Geology**: Coastal aquiclude limestones, elevated reefs **Elevation**: coastal, <600 m asl **Other Comments**: Special habitat type, Functionally important for anadromous species and others with marine/estuarine phases; *eg. Dunns River, Bluefields , Guts River, etc*
13	Western Limestone Complex	**AES #2.5 Permanent and ephemeral ponds and lakes.**	**Hydrology**: permanent and ephemeral ponds and lakes **Geology**: Usually alluvium **Elevation**: <600m above sea level **Other Comments**: Special habitat type, high biodiversity, rare species; *eg. Wallywash Pond*
14	Western Limestone Complex	**AES #2.6 Freshwater wetlands**	**Hydrology**: Semi-permanently flooded evergreen sclerophyllous forest, Seasonally/ temporally flooded grassland, Seasonally/ temporally flooded forb vegetation, Semi-permanently flooded grassland **Geology**: Alluvium **Elevation**: <600 m above sea level **Other Comments**: High biodiversity, special habitat type, functionally important for many FW species; *eg. Black River Upper Morass*
15	Western Limestone Complex	**AES #2.9- Med-sized, low altitude, non karstic, streams**	**Hydrology**: 4th to 6th order **Geology**: Central Inlier yellow limestones **Elevation**: <600 m asl **Other Comments**: Overlying the Central Inliers (yellow limestone and clastics). May be a centre of aquatic endemism in Jamaica; *eg. Main tributaries of Rio Minho and Black River*

	EDU	Freshwater target	Descriptive details
		Endemic Fish: *Gambusia melapleura, Gambusia wrayi, Limia melanogaster, Cubanichthys pengelleyi.*	
		Endemic turtle: *Pseudemys terrapen*	

Conservation Targets cross referenced with IUCN habitat categories (IUCN 2004c)

Aquatic Ecological System Target	TNC/CERP	IUCN
AES #1.1- Small high altitude streams	**Headwaters/ Small rivers**	**5.1. Permanent Rivers/Streams/Creeks [includes waterfalls]**
AES #1.2- Med-sized, low altitude streams	**Medium Rivers**	**5.1. Permanent Rivers/Streams/Creeks [includes waterfalls]**
AES #1.3- Large, low-altitude streams	**Large rivers**	**5.1. Permanent Rivers/Streams/Creeks [includes waterfalls]**
AES #1.4-Small coastal springs and streams	**Coastal Aquiclude and Springs**	
AES #1.6- Freshwater wetlands	**Freshwater wetlands**	**5.4. Bogs, Marshes, Swamps, Fens, Peatlands**
AES #1.7- Permanent and ephemeral ponds	**Lakes**	**5.7. Permanent Freshwater Marshes/Pools [under 8 ha], 5.5.**
AES #1.8- Freshwater caves		
AES #1.9- Springs		**5.9. Freshwater Springs and Oases,**
AES #2.1- Small, high altitude non-karstic streams	**Headwaters/ Small rivers**	**5.1. Permanent Rivers/Streams/Creeks [includes waterfalls]**
AES #2.2 Large low altitude streams (Alluvial, coastal influenced rivers,)	**Large rivers**	**5.1. Permanent Rivers/Streams/Creeks [includes waterfalls]**
AES #2.3a- Karstic aquatic systems: freshwater caves		**5.18. Karst and Other Subterranean Hydrological Systems [inland]**
AES #2.3b- Karstic aquatic systems: karstic streams		**5.18. Karst and Other Subterranean Hydrological Systems [inland]**
AES #2.3c- Karstic aquatic systems: springs		**5.9. Freshwater Springs and Oases, 5.18. Karst and Other Subterranean Hydrological Systems [inland]**
AES #2.4-Small coastal springs and streams	**Coastal Aquiclude and Springs**	**5.9. Freshwater Springs and Oases,**
AES #2.5 Permanent and ephemeral ponds and lakes.	**Lakes**	**5.7. Permanent Freshwater Marshes/Pools [under 8 ha], 5.5. Permanent Freshwater Lakes [over 8 ha]**
AES #2.6 Freshwater wetlands	**Freshwater wetlands**	**5.4. Bogs, Marshes, Swamps, Fens, Peatlands**
AES #2.9- Med-sized, low altitude, non karstic, streams	**Medium Rivers**	**5.1. Permanent Rivers/Streams/Creeks [includes waterfalls]**

Key ecological Attributes

Key Ecological Attributes (KEAS) are defined as critical patterns of biological structure and function, critical ecological processes, environmental regimes, and other environmental constraints that shape a biological system (or conservation target). A conservation target has integrity when all its key ecological factors remain intact and function within their natural range of variation. Such factors are described as 'key' because if any are significantly altered or eliminated, the conservation target either ceases to exist or permanently transforms into another type of system. The KEAs for freshwater conservation targets are described in the table below.

Freshwater target	Key Ecological Attributes
AES #1.1- Small high altitude streams	**Water Quality:** Temperature, Dissolved oxygen, Turbidity **Physical Habitat Quality:** Allochthonous inputs, Substrate composition & stability, Degree of shading/ exposure **Aquatic Biology and Trophic Relationships**: Allochthonous inputs, Aquatic community composition **Environmental Regimes**: Sedimentation regime, Hydrological regime
AES #1.2- Med-sized, low altitude streams	**Water Quality:** Turbidity, Nutrients, Temperature, **Physical Habitat Quality:** Riffle-pool pattern, Substrate composition & stability **Aquatic Biology and Trophic Relationships:** Aquatic community composition and structure, Allochthonous inputs and Autochthonous production **Environmental Regimes:** Sedimentation regime
AES #1.3- Large, low-altitude streams	**Water Quality**: Nutrients, Turbidity **Physical Habitat Quality**: Substrate composition & stability **Aquatic Biology and Trophic Relationships**: Autochthonous production, Aquatic community structure and composition **Environmental Regimes:** Flood regime, Sedimentation regime
AES #1.4-Small coastal springs and streams	**Water Quality**: Nutrients, Salinity **Physical Habitat Quality**: **Aquatic Biology and Trophic Relationships**: Allochthonous inputs, Autochthonous production, Aquatic community structure and composition **Environmental Regimes:** Hydrological regime
AES #1.6- Freshwater wetlands	**Water Quality**: Nutrients, **Physical Habitat Quality**: Substrate composition & stability **Aquatic Biology and Trophic Relationships**: Allochthonous inputs, Aquatic community structure and composition **Environmental Regimes:** Flood regime, Sedimentation regime
AES #1.7- Permanent and ephemeral ponds	**Water Quality**: Nutrients **Physical Habitat Quality:** Autochthonous production **Aquatic Biology and Trophic Relationships:** Allochthonous inputs **Environmental Regimes:** Hydrological regime, Sedimentation regime
AES #2.1- Small, high altitude non-karstic streams	**Water Quality**: Dissolved Oxygen, Turbidity, Temperature **Physical Habitat Quality:** Substrate composition & stability, degree of shading/exposure, riffle pool pattern **Aquatic Biology and Trophic Relationships**: Aquatic community composition **Environmental Regimes**: Hydrological regime
AES #2.2 Large low altitude streams (Alluvial, coastal influenced rivers,)	**Water Quality:** Nutrients, Turbidity, Salinity **Physical Habitat Quality:** Connectivity of upstream/ downstream reaches, **Aquatic Biology and Trophic Relationships**: Autochthonous production, Aquatic community structure and composition **Environmental Regimes**: Flood regime

Freshwater target	Key Ecological Attributes
AES #2.3a- Karstic aquatic systems: freshwater caves	**Water Quality**: Hardness, Nutrients, Dissolved Oxygen **Physical Habitat Quality**: Connectivity of limestone conduits, Degree of shading/exposure, low disturbance, Substrate composition & stability **Aquatic Biology and Trophic Relationships**: Allochthonous inputs, Characteristic cave community composition **Environmental Regimes:** Sedimentation and hydrological regimes
AES #2.3b- Karstic aquatic systems: karstic streams	**Water Quality**: Hardness, Nutrients, Dissolved Oxygen **Physical Habitat Quality**: Connectivity of limestone conduits, Degree of shading/exposure, Substrate composition & stability **Aquatic Biology and Trophic Relationships**: Allochthonous inputs, **Environmental Regimes:** Sedimentation and hydrological regimes
AES #2.3c- Karstic aquatic systems: springs	**Water Quality**: Hardness, Nutrients, Dissolved Oxygen **Physical Habitat Quality**: Connectivity of limestone conduits, Degree of shading/exposure, Substrate composition & stability **Aquatic Biology and Trophic Relationships**: Allochthonous inputs, **Environmental Regimes:** Sedimentation and hydrological regimes
AES #2.4-Small coastal springs and streams	**Water Quality**: Nutrients, Salinity **Physical Habitat Quality**: **Aquatic Biology and Trophic Relationships**: Allochthonous inputs, Autochthonous production, Aquatic community structure and composition **Environmental Regimes:** Hydrological regime
AES #2.5 Permanent and ephemeral ponds and lakes.	**Water Quality**: Turbidity, Nutrients **Physical Habitat Quality:** Autochthonous production **Aquatic Biology and Trophic Relationships:** Allochthonous inputs **Environmental Regimes:** Hydrological regime, Sedimentation regime
AES #2.6 Freshwater wetlands	**Water Quality:** Nutrients, Turbidity **Physical Habitat Quality**: Size **Aquatic Biology and Trophic Relationships**: Aquatic community structure and composition, Autochthonous production **Environmental Regimes**: Hydrological regime, Sedimentation regime
AES #2.9- Med-sized, low altitude, non karstic, streams	**Water Quality:** Turbidity, Nutrients, Temperature, **Physical Habitat Quality:** Riffle-pool pattern, Substrate composition & stability **Aquatic Biology and Trophic Relationships:** Aquatic community composition and structure, Allochthonous inputs and Autochthonous production **Environmental Regimes:** Sedimentation regime
Endemic Fish: *Gambusia melapleura, Gambusia wrayi, Limia melanogaster, Cubanichthys pengelleyi.*	**Water Quality:** Turbidity, Nutrients, Temperature, **Physical Habitat Quality:** Substrate composition & stability, Hiding places **Aquatic Biology and Trophic Relationships:** Aquatic community composition, competition, predation, Allochthonous inputs **Environmental Regimes:** Sedimentation regime
Endemic turtle: *Pseudemys terrapen*	**Water Quality:** Turbidity, Nutrients, Temperature, **Physical Habitat Quality:** Substrate composition & stability, Hiding places **Aquatic Biology and Trophic Relationships:** Aquatic community composition, competition, predation, Allochthonous inputs **Environmental Regimes:** Sedimentation regime

APPENDIX 3: Freshwater Conservation Target Quantitative Goal calculations

Quantitative conservation goals were modelled for all targets according to three schemes: 1) 10% of all habitats according to the 10-year goal, 2) 20% of all habitats, and 3) a progressive and adaptive scheme. The 10-year goal was recommended by TNC's Global Priorities Group in 2003 and aims to conserve 10% of all major habitats.

EDU	Target name	code	Total (km, Ha, or # of occurrences)	10%	20%	30%	Adaptive %	Adaptive Amount
Blue Mountain EDU	High altitude, headwater streams	630	584.92	58.49	116.98	**175.47**	**15**	87.74
	Medium-sized streams	631	2238.73	223.87	447.75	**671.62**	**10**	223.87
	Large low-altitude streams	632	38.22	3.82	7.64	**11.47**	**50**	19.11
	Coastal springs and streams	633	138.20	13.82	27.64	**41.46**	**25**	34.55
	Freshwater wetlands	634	220.94	22.09	44.19	**66.28**	**50**	110.47
	Lakes and ponds	635	43.07	4.31	8.61	**12.92**	**25**	10.77
	Springs	646	109	11	22	**33**	**10**	11
	Freshwater caves	647	9	1	2	**3**	**50**	5
Western Limestone EDU	Small high altitude headwater streams: non karstic	636	147.81	14.78	29.56	**44.34**	**25**	36.95
	Large low-altitude streams	637	418.76	41.88	83.75	**125.63**	**30**	125.63
	Karstic aquatic systems: Freshwater caves	638	214	21	43	**64**	**10**	21
	Karstic aquatic systems: Springs	639	417	42	83	**125**	**10**	42
	Karstic aquatic systems: Karstic streams	640	1505.35	150.54	301.07	**451.61**	**10**	150.54
	Coastal springs and streams	641	166.33	16.63	33.27	**49.90**	**30**	49.90
	Lakes and ponds	642	801.79	80.18	160.36	**240.54**	**25**	200.45
	Freshwater wetlands	643	12893.59	1289.36	2578.72	**3868.08**	**25**	3223.40
	Medium-sized streams: non karstic	645	1850.54	185.05	370.11	**555.16**	**10**	185.05
Fine Filter	*C. pengellyi*	650	8	7	1.6	**2.4**	**50**	4
	G. melapleura	651	2	1	0.4	**0.6**	**50**	1
	G. wrayi	652	15	2	3	**4.5**	**30**	5
	L. melanogaster	653	23	8	4.6	**6.9**	**25**	6
	P. terrapen	654	18	9	3.6	**5.4**	**25**	5

For the adaptive goal scheme, the more abundant or widespread conservation targets were assigned smaller conservation goals than the less abundant and more localised targets (Groves *et al*, 2000). Higher goals were also assigned to those that are presently un- or under-represented in Jamaica's Protected Area network.

Conservation goals based on target distributions from Groves et al, 2000

Target Abundance	Conservation Goal
Rare	50%
Uncommon	25%
Common	15%
Very Common	10%

Table 14: Abundance classes for adaptive goals

System	Total	Abundance	Goal
Streams	0-100km	Rare	50
Streams	100-500km	Uncommon	25
Streams	500-1000km	Common	15
Streams	>1000km	Abundant	10
Lake/ponds	845 ha	Uncommon	25
Eastern Wetlands	221ha	Rare	50
Western Wetlands	12894ha	Uncommon	25
Eastern springs	109	Abundant	10
Western springs	417	Abundant	10
Eastern caves	9	Rare	50
Western caves	214	Abundant	10
Fine filter targets		Uncommon	50

APPENDIX 4: Ecological Integrity Analyses

Method 1:
DIRECT: Key Ecological Status values

- Key Ecological Attributes (KEA) were determined for each AES.
- The status of each key ecological attribute for each AES occurrence was estimated on a scale of between 0 and 1. Questionnaires were developed to collect this information from experts.
- The weighted average of the key ecological attributes for each occurrence was determined and taken as the estimation of ecological integrity.

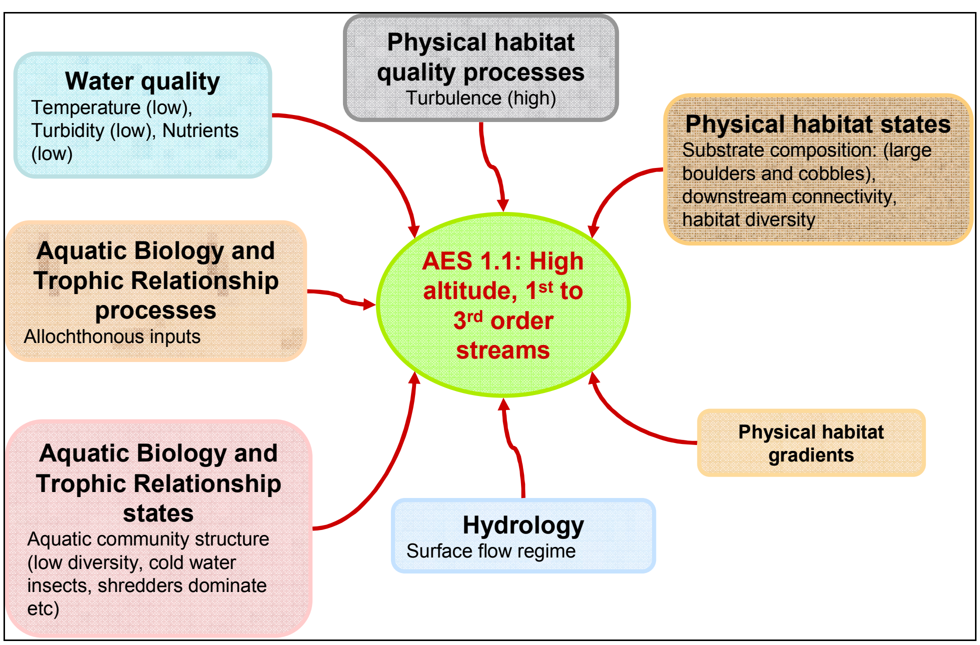
Comments on the main stresses and other issues affecting aquatic ecosystems were also collected with in the survey questionnaires. The information collected on the status of KEAs for each target occurrence could not be used for a viability analysis. However, the supporting commentary on stresses was useful for defining the main threats affecting aquatic ecosystems and for defining data gaps.

Main Steps in Viability Assessment

1. Determine and rank Key Ecological Attributes
2. Eliminate attributes which human activities cannot influence such as bedrock type or elevation.
3. Estimate the present status of each KEA for each occurrence of a target
4. Calculate the overall integrity of each occurrence of each target based on the average status of all key ecological attributes
5. Integrate KEA data with other information such as from NEPA and WRA

Determining the Key Ecological Attributes of ecosystem targets
This is a consultative process in which experts choose from a long list of possible ecological attributes those attributes considered key to the existence of the conservation target.

Figure 1: Key ecological attributes of headwater streams in eastern Jamaica



Rating the status of each Key Ecological Attribute for each occurrence of target

At this step, an attempt is made to quantify the status of each key ecological attribute for each example of a target. It is assumed that the natural range of variation lies between 0.4 and 0.7. The experts then ask themselves the following questions: 'Is the key ecological attribute within or outside of its natural range of variation?', 'How far within the natural range of variation is the attribute?' or 'How far outside its natural range of variation is the attribute?' The degree of uncertainty about the information generated is captured by including the minimum and maximum values of the status of the attribute. Table 1 illustrates how the information was captured for medium sized streams in the Yallahs and Swift River drainage basins.

Table 15: An example of key ecological attribute rating: comparison of 4th to 6th order streams in the Swift River and Yallahs Basin

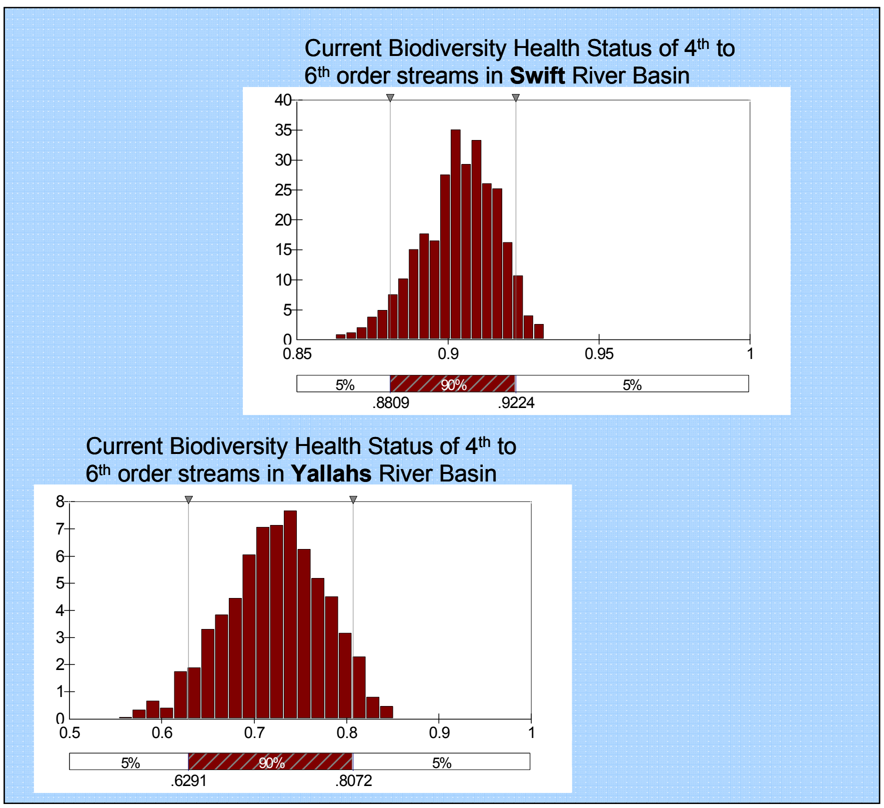
Eastern EDU: 4th to 6th order streams below 600 metres above sea level

Occurrence	Key Ecological Attribute	Estimate of KEA viability status			Comments
		Minimum	Maximum	Most Likely	
Swift River Basin	*Aquatic community structure*	0.4	0.7	0.6	system is in good shape
	Hydrological regime	0.4	0.7	0.5	
	Habitat diversity	0.4	0.7	0.6	
	Nutrient levels	0.4	0.7	0.6	May be impacted by coffee fertilizers
	Sedimentation Regime	0.4	0.7	0.5	
	Turbidity	0.4	0.7	0.6	
Yallahs Basin	*Aquatic community structure*	0.2	0.6	0.35	Community structure is more simplified because of nutrients inputs
	Hydrological regime	0.75	0.95	0.85	Has a flashier hydrograph (more and pronounced peaks and troughs) compared to a 'normal' stream.
	Habitat diversity	0.2	0.6	0.4	Low habitat diversity, substrate often covered with gravel and silt caused by sedimentation
	Nutrient levels	0.65	0.9	0.8	Coffee pulpery and chicken farms present in the area
	Sedimentation Regime	0.75	0.95	0.85	Disrupted by sand mining, see Ministry of Mining for information
	Turbidity	0.6	0.9	0.75	Soil erosion and sand mining causes high turbidity

					levels

Rating the integrity of each occurrence of a target using Key Ecological Attributes
The information gathered from experts in table 1 is computer-analysed to generate estimates of ecological integrity. The integrity of each occurrence of a target as estimated at any one point in time is called of a target is called the *current biodiversity health*. This measure is a weighted average of the displacement of the key ecological attributes from their natural ranges of variability. If all key attributes fall within their natural range of variation, then the current biodiversity health estimate is '1'. As more key attributes fall outside of their natural range of variation, the measure of current biodiversity health ranges towards '0'. In the comparison of medium-sized streams in the Swift and Yallahs Basins (Figure 6), the streams in Swift River Basin clearly have a higher biodiversity health rating than those in Yallahs Basin.

Figure 2: Illustration of how the integrity of conservation target occurrences are rated



Integration of target integrity information with other data
The information on the current biodiversity health of each occurrence of the conservation targets is then mapped using a GIS database. This information is then overlaid and integrated with other information such as the Watershed Management Unit classification of the Sustainable Watershed Branch of NEPA and the unpublished stream reach quality classification data of WRA.

APPENDIX 5: Threats to freshwater biodiversity

Threat Group	Activity	Key Ecological Factor Impairment	Indicators
Land Use and Cover Changes (LUCC) (especially agriculture and grazing)	Agriculture and grazing (sugar cane, coffee, other tree crops, other short term crops)	**Sedimentation regime**- usually increased sediment load **Water quality-** increased turbidity, increased nutrients, probably toxic agrochemicals **Aquatic biology and Trophic Relationships**- reduced and/or changed allochthonous inputs, change in community structure and composition	➢ Projected rates of erosion: ○ This will need to be modeled based on indicators such as land use and cover; soil type; slope; and watershed flow. ➢ Proximity of water sources to agroindustrial enterprises (pesticides and fertilizer contamination)
	Urbanisation (see below)		➢
	Agroforestry	**Hydrological Regime**- decreased infiltration and faster runoff **Aquatic biology and Trophic Relationships**- reduced and/or changed allochthonous inputs	➢
	Filling in and development of wetlands	**Hydrological Regime**- decreased infiltration and faster runoff	➢ Proximity of wetland areas to areas targeted for residential, industrial or tourist development.
Infrastructure (INF)	Urbanisation (increase in paved surfaces, including the contributing area and channel, removal of riparian vegetation)	**Hydrological Regime**- decreased infiltration and faster runoff **Physical Habitat Quality**- substrate composition changed to smooth impermeable surface, channel morphology changed **Aquatic biology and Trophic Relationships**- reduced allochthonous inputs	➢ Total area of Urban areas ➢ Proximity to major infrastructure: principally: ○ Primary and secondary roads ○ Dams ○ Reservoirs. ➢ Size and particular type of infrastructure. ➢ Plans for future development of major infrastructure.

Threat Group	Activity	Key Ecological Factor Impairment	Indicators
	Dams	**Physical habitat Quality**- Longitudinal connectivity disrupted, erosion/deposition balance disrupted, flow patterns disrupted, **Hydrological Regime-** Surface flow and flood cycle disrupted **Aquatic Biology and Trophic Relationships**- Aquatic community structure changes, migration routes disrupted	
	Road Crossings, culverts	**Physical habitat Quality**- Longitudinal connectivity disrupted, erosion/deposition balance disrupted, flow patterns disrupted, **Aquatic Biology and Trophic Relationships**- Aquatic community structure changes, migration routes disrupted	
Invasive species (IS)	➢ Invasive animals (Tilapia (*Oreochromis mossambica*), *Thiara granifera*, Australian red-claw (*Cherax* spp), carp	➢ **Aquatic Biology and Trophic Relationships-** Modified aquatic community structure and composition, modified biotic interactions	• Actual or likely presence of given invasives by type (presence may also be indicated by soil disturbance or horticultural activities) • National policies related to invasive species (importation guidelines) • Proximity to aquaculture operations by size and type • Location and frequency of stocking of fisheries by predominant species.
	➢ Invasive aquatic and terrestrial plants water hyacinth (*Einchornia. crassipes*), bamboo (*Bambusa vulgaris*), rose apple (*Syzygium jambos*))	➢ **Aquatic Biology and Trophic Relationships-** Modified aquatic community structure and composition, modified allochthonous inputs ➢ **Physical habitat Quality**- modified flow patterns, modified substrate	

Threat Group	Activity	Key Ecological Factor Impairment	Indicators
Industrial discharge into freshwater sources (ID)	Food-processing industries effluent discharge	**Water Quality-** Increased particulate and DOM, increased turbidity ,increased temperature, toxins introduced **Aquatic Biology and Trophic Relationships-** Increased allochthonous inputs, modified aquatic community structure	• Proximity of water source to existing industrial areas by size and predominant type of industry. • Existence of State regulations, organizations and procedures to monitor water quality. • Water quality data for major freshwater sources (esp. rivers and lakes)
	➢ Bauxite Processing		
Landfills/dumps (DUMP)	➢ Effluent seepage	➢ **Water Quality-** Increased particulate and DOM, increased turbidity, toxins introduced	• Proximity of major landfills to key freshwater sources
	➢ Solid Waste contamination	➢ **Physical habitat Quality**- Longitudinal connectivity disrupted, connectivity of limestone conduits disrupted, erosion/deposition balance disrupted, flow patterns disrupted	
Incompatible sewage treatment/discharge (SEW)	➢ Organic pollution	➢ **Water Quality**- Decreased dissolved oxygen, Increased particulate and DOM, increased turbidity, toxins introduced	• Sewage outfalls and proximity of outfalls to freshwater systems • Level of Sewage treatment • Proximity of major tourist areas. • Population density close to water source. • Water quality data for major freshwater sources.

Threat Group	Activity	Key Ecological Factor Impairment	Indicators
Groundwater withdrawal (GWAT)	➢ Saline Intrusion ➢ Reduced flows	➢ **Water Quality**- Increased salinity ➢ **Aquatic Biology and Trophic Relationships-** Modified aquatic community composition ➢ **Hydrological Regime**- reduced baseflow	• Proximity to major infrastructure by size and type (major well systems) • Data on present and future water demand vs. capacity. • Rates of population growth over space and time. • Data on water use per sector (agricultural, industrial, residential)
Surface water withdrawal (SWAT)	➢ Saline Intrusion Reduced flows	➢ **Hydrological Regime**- reduced surface flows, reduced groundwater recharge?	• Proximity to infrastructure by size and type (dams and aqueduct sources) • Present and future water demand vs. capacity. • Location of major aqueduct sources. • Proximity to major irrigation zones.
Irrigation infrastructure (IRR)	➢ Micro dams	➢ **Hydrological Regime-** ➢ **Water Quality**- increased nutrients	• Proximity to major irrigation zones. • Proximity to planned or potential irrigation zones.
Over fishing (OFIS)	Overfishing	➢ **Aquatic Biology and Trophic Relationships-** Modified aquatic community composition and structure, modified biotic relationships	• Location of freshwater fishing sites by type. • Species and amounts caught
Resource Extraction and Mining (RE)	➢ Quarrying ➢ Bauxite Mining ➢ Sand mining	➢ **Water Quality**- Increased turbidity, Alkaline pollution from red lakes. ➢ **Aquatic Biology and Trophic Relationships-** Modified aquatic community structure and composition ➢ **Physical habitat Quality**- modified substrate composition, reduced allochthonous inputs	• Proximity to mining areas by type and size (especially gravel, sand and gold mining). • Proximity to areas of planned future mining/oil drilling. • Proximity to areas identified as potential mining or oil drilling areas. • Data on gravel and sand extraction from riverbeds and margins.

APPENDIX 6: Cost Surface inputs

Cost Surface

A trial cost surface was developed for the June 2005 portfolio runs. The GIS inputs for the cost surface were derived from two sources: the NEPA watershed classification and draft WRA stream water quality atlas. In the NEPA classification, watershed management units (WMUs) were ranked as poor (severely degraded), fair (degraded), good (less degraded), and very good (least degraded) according to aggregate scores derived from the following the following attributes; geology, soil erosion susceptibility, slope (derived from DEM), land use and vegetation cover, landslide potential, stream density and road density. A unique ID was assigned to each degradation class and the WMU rank shapefile was extracted into planning units just like the biological targets.

The draft stream water quality atlas is a database with three measures of stream water quality for the main rivers of Jamaica: 1) status with respect to ambient water quality standards, 2) Revell ratio which measures water quality in relation to saline impacts, and 3) nitrate levels which is based on mean nitrate levels for a specified period. For the cost surface, the status of these streams with respect to ambient water quality was used. Three classes were derived, excellent, fair and poor and each class was assigned a unique ID. As in the WMU ranks, the stream quality shapefile was extracted into the planning units.

Cost factors were assigned to each class as shown in the table below:

Cost Input	Classes	Tgt_id	Cost factor
Stream water quality	Excellent	10	2000
	Fair	20	3000
	Poor	30	4000
Watershed Degradation level	Poor	1	2
	Fair	2	1.33
	Good	3	1.66
	Very Good	4	1

The cost of each planning unit was then calculated as shown in the following extract from the cost spreadsheet.

Pu_id	Tgt_id	Amount	Cost Factor	Weighted amount	Total for Pu	Factor Reduction (/7779005)	Default cost (1.00) + add on cost
52	1	2348604.8864	2	4697209.77	14407825.17	1.852142513	2.852142513

52	20	3236.8718	3000	9710615.40			
58	1	2598076.2114	2	5196152.42	6584855.423	0.846490746	1.846490746
58	20	462.9010	3000	1388703.00			
65	1	2598076.2114	2	5196152.42	13225371.02	1.700136671	2.700136671
65	20	2676.4062	3000	8029218.60			
72	1	2598076.2114	2	5196152.42	22219119.62	2.856293408	3.856293408
72	20	5674.3224	3000	17022967.20			
80	1	2598076.2114	2	5196152.42	35876522.82	4.611968313	5.611968313
80	20	8640.8360	3000	25922508.00			
80	30		1189.4656	4757862.40			

The final cost surface was developed using a Human Activity Surface (HAS) extension in ArcGIS 9.1. The inputs and calculations for this cost surface are listed in the following table.

Freshwater cost surface inputs

Activity	Intensity	Extent of influence (km)	Effects	Shapefile	References/notes
Banana plantation	8	5	Very intensive use of pesticides and fertilisers, also generates solid waste, some evidence of bioaccumulation in aquatic systems, increased runoff and sedimentation	ja_ag_bananas.shp	MRAG, www.bananalink.org.uk/impact,
Sugar cane plantation	6	5	Very intensive use of pesticides and fertilisers, some sedimentation	ja_ag_sugarcane_plantation.shp	
Small-scale agric and grasslands	5	3	Very intensive use of pesticides and fertilisers, some sedimentation	ja_ag_small_scale_and_grasslands.shp	
Tree crops and agro-forestry	3	2	Some use of pesticides and fertilisers, some sedimentation	ja_ag_tree_crop_and agroforestry.shp	
Bauxite Processing (presence/absence)	10	8	Biological and Physico-chemical evidence of alkaline contamination up to 5 miles downstream of Rio Cobre.	Ja_bauxite_plants.shp	Damian Nesbeth pers. comm.. MPhil research on effect of bauxite effluent on Rio Cobre.
Sewage outfalls (presence/absence)	8	10	Reduced DO, increased BOD and other toxins, reduced species diversity, and evenness	ja_sewage_outfalls.shp	Lytle Creek, Ohio. Gaufin and Tarzwell 1956
Urbanised area	6	5	Impervious surfaces, disrupt flow regime, reduce base flow, pollutants introduced directly into aquatic systems.	**ja_urban_areas.shp**	Urbanisation impacts on Aquatic resources (unpublished paper), Miltner, White, Yoder (2003) The biotic integrity of streams in urban and sub-urbanising landscapes. *Landscape and Urban Planning*, Elsevier
Sewage seepage (0-25 pit latrines/km2)	0	0.5	Reduced DO, increased BOD and other toxins, reduced species diversity, and evenness	Ed_toilet_facility.shp	
Sewage seepage (25-50 pit latrines/km2)	1	2			
Sewage seepage (50-500 pit latrines/km2)	3	5			

Activity	Intensity	Extent of influence (km)	Effects	Shapefile	References/notes
Sewage seepage (500-5000 pit latrines/km2)	6	10			
Sewage seepage (>5000 pit latrines/km2)	8	20			
Dams (HEP and other high dams)	8	30	Caribbean streams dominated by amphidromy among native fish and shrimp. Dams alter the habitats, hydrology, longitudinal migration, and facilitates exotic species invasions.	ja_dams_pts.shp	Holmquist, Schmidt, Yoshioka (1998) Effect of High Dam in PR stream *Conservation Biology* 12(3).
Dams (Irrigation)	5	30		ja_dams_pts.shp	Benstead, March, Pringle (1999) Effect of Low-head dam on PR stream, Ecological Applications
Excessive water abstraction (0-25% of basin total extracted)	0	0.1	Can disrupt instream flow requirements and hydrology, Can disrupt upstream/ downstream linkages like dams	ja_wmu_2015_abstraction_rates_jun05.shp	Benstead, March, Pringle (1999) Effect of Low-head dam on PR stream, Ecological Applications
Excessive water abstraction (25-50% of basin total extracted)	2	0.1			
Excessive water abstraction (50-75% of basin total extracted)	4	0.1			
Excessive water abstraction (75-100% of basin total extracted)	6	0.1			
Excessive water abstraction (>100% of basin total extracted)	8	0.1			
Sand Mining	6	5	Disrupts substrate, increases turbidty	ja_sand_mining.shp	
Limestone quarrying			Increases runoff and turbidity		
Bauxite mining	5	2	Increases runoff and turbidity	ja_bauxite_mining_areas.shp	
Cherax quadricarinatus (Australian redclaw)	4	0.1	Changes substrates, outcompetes native shrimp.	ja_fw_invasive_animal_cherax.shp	

Activity	Intensity	Extent of influence (km)	Effects	Shapefile	References/notes
Bambusa vulgaris (Bamboo)	4	1	Changes allochthonous inputs into aquatic systems	ja_terr_invasive_plant_bamboo.shp	
Natural Areas	-1	1	Mitigates other deleterious effects	Jamaic's Remaining Natural Areas-PASP.shp	

APPENDIX 7: **Protected Area Gap Assessment for Jamaica's freshwater**

DATA SETS:

The main inputs into the gap analysis were information on protected areas and freshwater biodiversity in GIS (geographic information systems) format as described below.

Protected Areas

Spatial data on the type and location of Jamaica's protected areas were obtained from National Environment and Planning Agency. The GIS layers were first edited to remove protected areas that contained no freshwater biodiversity. The layers were modified to remove areas of overlap which would have resulted in double and in many cases triple counting of the biodiversity in PAs. Because there was considerable spatial overlap among the different protected areas (e.g., most of Blue and John Crow Mountains National Park is also a Forest Reserve), it was necessary to rank the protected areas so that in areas of overlap there would be a primary protected area category followed by a secondary and tertiary if necessary(Table 1). Even then there was still overlap between the Negril Protected Area and Negril Great Morass Protected Area, both of which are declared under the NRCA Act. Consequently the larger of the two, Negril Protected Area was used for the final protected area network shapefile.

NATURAL RESOURCES CONSERVATION AUTHORITY

PROTECTED AREAS

PROTECTED AREA	DECLARATION DATE	*ACT*
Montego Bay Marine Park	June 5, 1992	NRCA
Blue and John Crow Mountains National Park	**February 26, 1993**	**NRCA**
Negril Environmental Protection Area	**November 28, 1997**	**NRCA**
Negril Marine Park	**March 4, 1998**	**NRCA**
Palisadoes/Port Royal Protected Area	**September 18, 1998**	**NRCA**
Coral Spring – Mountain Spring Protected Area	**September 18, 1998**	**NRCA**
Portland Bight Protected Area	April 22, 1999	NRCA
Ocho Rios Marine Park	**August 16, 1999**	**NRCA**
Mason River Protected Area	**November 14, 2002**	**NRCA**

Ocho Rios Protected Area	**April 7, 1966**	**BCA**
Port Royal Protected Area	**May 8, 1967**	**BCA**
Bogue Lagoon Creek Game Reserve, Montego Bay, St. James	December 12, 1963	WLPA
Kingston and St. Andrew Game Reserve	**April 15, 1971**	**WLPA**
Knapdale Game Reserve, St. Ann	**January 1963**	WLPA
Reigate Game Reserve, Manchester	**June 6, 1968**	**WLPA**
Stanmore Hill Game Reserve, St. Elizabeth	**July 19, 1988**	WLPA
Alligator Pond, Guts River and Canoe Valley Game Reserve, Manchester/Clarendon	**August 22, 1997**	**WLPA**
Amity Hall Game Reserve, St. Catherine	**August 22, 1997, amended July 28, 2004**	**WLPA**
Bogue Lagoon Creek Game Reserve, Montego Bay, St. James	**August 22, 1997**	**WLPA**
Glistening Waters Game Reserve, Falmouth, Trelawny	**August 22, 1997**	**WLPA**
The Great Morass Game Reserve, Holland Bay, St. Thomas	**August 22, 1997, amended July 28, 2004**	**WLPA**
The Lower Morass, Black River Game Reserve, St. Elizabeth	**August 22, 1997, amended in 1998**	**WLPA**
The Great Morass Game Reserve, Negril, Westmoreland/Hanover	**August 22, 1997**	**WLPA**
The Great Morass Game Reserve, Parottee, St. Elizabeth	**August 22, 1997**	**WLPA**
Upper Morass, Black River Game Reserve, St. Elizabeth	**August 22, 1997**	**WLPA**
Cabaritta Point Game Reserve, St. Catherine	**August 21, 1998**	**WLPA**
Long Island Game Reserve, Clarendon	**August 21, 1998**	**WLPA**
Mason River Savanna Game Reserve, Clarendon	**August 21, 1998**	**WLPA**
West Harbour, Game Reserve, Clarendon	**August 21, 1998, amended in 1999 and July 28, 2004**	**WLPA**
Portmore and Greater Portmore Game Reserve, St. Catherine	**July 28, 2004**	**WLPA**
Fairy Hill-Port Antonio Game Reserve, Portland	**July 28, 2004**	**WLPA**

BCA- Beach Control Act
NRCA-Natural Resources Conservation Authority Act
WLPA-Wild Life Protection Act

METHODS:

Protected Area Attributes
Three aspects of the Protected Area Network were analysed:

1) **Representation**: indicates whether the target is represented and replicated sufficiently in the PA network. This is measured by the amount and percentage of each target's distribution within each protected area.
2) **Ecological Integrity**: indicates whether the represented targets are in adequate ecological condition and whether factors such as connectivity particularly for freshwater systems are incorporated in the network.
3) **Management**: indicates whether the represented targets are protected in reality by the appropriate management systems.

Protection Benchmarks
The current protected area network was measured against the "10%" target commitment of the Jamaican Government. This target was based on the concept of terrestrial protected areas which does not apply to linear freshwater ecosystems such as rivers and streams and even subterranean systems. However, the freshwater benchmarks will be refined in the future as the conservation requirements of freshwater ecosystems are understood.

A more qualitative standard used in the analysis was "connectivity" which is an important attribute of freshwater ecosystems absolutely critical for their ecological integrity. Connectivity was highlighted because freshwater ecosystems are inherently dependent on ecological processes originating outside the protected area. For this, protected areas with significant freshwater biodiversity were individually evaluated according to how well longitudinal and horizontal connections were preserved in their design.

Freshwater Ecosystem Distribution in PAs
GIS software, specifically SPOT (Spatial Optimisation Tool, TNC 2001), was used to calculate the distribution of freshwater ecosystems in the protected area network. The protected areas shapefile prepared as described above was selected as *planning units* in the SPOT extension in ArcView 3.3. Freshwater ecosystem shapefiles were then extracted (i.e. overlaid and intersected with) the protected area planning units. The amount of each target contained in each protected area was then calculated from the resulting distribution database.

RESULTS:

Representation (Table 4)

10 of 17 freshwater systems are adequately represented in Jamaica's protected area network. This implies that 59% of the island's freshwater biodiversity is protected and 41% unprotected. Freshwater ecosystems in the west of the island are relatively well-

represented in a network comprising a national park, forest and game reserves. In the east, there were serious gaps. Apart from Blue and John Crow Mountains National Park (BJCMNP) which includes a large proportion of high altitude streams, most freshwater systems, such as low altitude streams and wetlands are excluded in the east.

Major Gaps in Blue Mountains

- Blue Mountain large streams
- Blue Mountain lakes and ponds
- Blue Mountain freshwater wetlands
- Blue Mountain coastal streams

Major Gaps in Western limestone complex:

- Western springs
- Western karstic streams
- Western coastal springs

Protection opportunities:
Table 3 outlines significant opportunities for freshwater biodiversity conservation that lie within the existing protected area network. It is expected that any modifications to Jamaica's Protected Area Network would use these protected areas as nuclei.

Table 16: Protected areas containing significant freshwater biodiversity

Category	Representation
National and Marine Parks	1) BJCMNP- A high altitude national park that protects most of the headwater streams (62%) and much of the medium sized low altitude streams (14%) in eastern Jamaica. 2) Portland Bight Protected Area- a terrestrial and marine protected area that includes 11% of large streams, 11% ponds and lakes, 7% medium sized streams, freshwater caves and springs in western Jamaica 3) Negril Environmental Protection Area- a terrestrial and marine protected area that includes 29% of freshwater wetlands, ponds and lakes (7%) and coastal springs(5%) in western Jamaica
Forest Reserves	1) Rockfort Forest Reserve- This includes 1 of 9 freshwater caves in Blue Mountains 2) Deeside/Peru Mountain Forest Reserves- protect 13 freshwater caves in the Western Limestone Complex
Game reserves	1) The Great Morass Game Reserve, Parottee- includes 5% of Western freshwater wetlands and is < 200m away from Jamaica's largest natural freshwater lake. 2) Upper Morass Black River Game Reserve- includes 11% of Western freshwater wetlands. 3) The Lower Morass Game Reserve- includes 6% of western large streams and 37% of western freshwater

Category	Representation
	wetlands.
Fish sanctuary	1) Bowden Fish Sanctuary- includes only 2% of Blue Mountain Freshwater Wetlands but is surrounded on its landward edge by a small but significant freshwater wetland which is rare in eastern Jamaica.
Proposed Protected Areas**	Although the list of Proposed Protected Areas is incomplete, two proposed areas are outstanding: 1) Wider Black River Wetlands and Coastal Area- includes 11% of Western ponds and lakes. 2) Port Antonio proposed Protected Area- includes 3 of 9 eastern freshwater caves and 6% of Eastern Coastal streams. Is also adjacent to main stem of Rio Grande, a major eastern river.

Ecological Gaps

Freshwater ecosystems are maintained by a specific combination of five ecological factors:

1) Hydrologic Regime
2) Water physico-chemistry regime
3) Physical habitat conditions
4) Connectivity
5) Biological Composition and Interactions

The design of the protected areas and layout of the network indicates whether connectivity was incorporated into the protected areas. The other four factors are incorporated PA management strategies. The PAs mentioned above were not specifically designed to preserve these ecological factors and the integrity of freshwater ecosystems. Furthermore, the island's rivers, wetlands and ponds are yet to be regarded as whole systems. This accounts for the fact that no protected areas in Jamaica cover complete river systems from headwaters to the coast. The main ecological gap in the design of Jamaica's protected areas is that of connectivity.

Category	Protected Area	Ecological Gaps
National and Marine Parks	1) BJCMNP-	A connection with low altitude streams and coastal areas is required in at least one watershed.
	2) Portland Bight Marine Protected Area	A connection with upstream areas along Rio Minho is required to ensure longitudinal connectivity
	3) Negril Environmental Protection Area	No gap detected: Encompasses an entire watershed.

Category	Protected Area	Ecological Gaps
Forest Reserves	1) Rockfort Forest Reserve-	Connections are unclear
	2) Deeside/Peru Mountain Forest Reserves-	Connections with downstream Martha Brae and Black River are required to ensure longitudinal connectivity. NB. Black River connectivity and hydrological regime may be compromised by the Magotty Dam.
Game reserves	1) The Great Morass Game Reserve, Parottee-	Excludes major freshwater ecosystem (Wallywash pond) <200m from the PA.
	2) Upper Morass Black River Game Reserve-	Connections with upstream and downstream Black River are required to ensure longitudinal connectivity.
	3) The Lower Morass Game Reserve-	Connections with upstream Black River and/or YS River are required to ensure longitudinal connectivity.
Fish sanctuary	1) Bowden Fish Sanctuary-	Connections with inland wetlands and streams are required to ensure lateral and longitudinal connectivity.
Proposed Protected Areas	1) Wider Black River Wetlands and Coastal Area-	Connections with upstream Black River and/or YS River are required to ensure longitudinal connectivity
	2) Port Antonio Proposed Protected Area-	Connections with upstream areas in Drivers River watershed are required to ensure longitudinal connectivity

Management gaps
This assessment does not include an in-depth analysis of protected area management gaps. However, the absence of management plans and systems that include freshwater ecosystems indicates that there is no management of freshwater ecosystems in Jamaica's protected areas.

Evaluating the management effectiveness of Jamaica's protected area system should ideally be a collaborative and participatory process. According to IUCN this evaluation should include the following representatives with varying degrees of involvement: local managers, senior agency managers, different tiers within government agencies, local communities, indigenous groups, NGO's, donors, international convention staff, and private sector bodies involved in PA management (Hocking *et al*. 2000).

Framework for assessing management effectiveness of protected areas and protected area systems (World Commission on Protected Areas)

Elements of evaluation	Context	Planning	Input	Process	Output	Outcome
Explanation	*Where are we now?* Assessment of importance, threats and policy environment	*Where do we want to be?* Assessment of protected area design and planning	*What do we need?* Assessment of resources needed to carry out management	*How do we go about it?* Assessment of the way in which management is conducted	*What were the results?* Assessment of the implementation of management programmes and actions; delivery of products and services	*What did we achieve?* Assessment of the outcomes and the extent to which they achieved objectives
Criteria that are assessed	Significance Threats Vulnerability National context	Protected area legislation and policy Protected area system design Reserve design Management planning	Resourcing of agency Resourcing of site Partners	Suitability of management processes	Results of management actions Services and products	Impacts: effects of management in relation to objectives
Focus of evaluation	Status	Appropriateness	Resources	Efficiency and appropriateness	Effectiveness	Effectiveness and appropriateness

Nevertheless, given that protected areas in Jamaica were not designed to sustain the ecological integrity of freshwater systems, a more fundamental gap assessment may be appropriate. Such a preliminary assessment of management gaps in Jamaica may ask simple questions, such as “Is there a management plan for the protected area?”, “Does the plan provide for the management and abatement of threats to freshwater systems within the protected area?”, “Are the strategies being implemented?”, “Are freshwater systems being monitored for their ecological integrity?”, “Are there results?”

BJCMNP is the only PA to have a current and approved management plan. Others, such as Negril Marine park, Negril Environemntal Protection Area, Palisadoes/Port Royal Protected Area, and Ocho rios marine park have drafted management plans. However the majority of PAs do not yet have management plans.

ASSESSMENT LIMITATIONS

1) Data- particularly on FW biodiversity, this was resolved using FW habitats and ecological processes as representatives
2) Management data

APPENDIX 8 Watershed Prioritisation Calculations

Watershed Prioritisation Calculations: Biological Importance

EDU	WMU name	Habitat diversity (# habitats in WMU/total in EDU)	# species targets	Fine Filter diversity (# species/ total # of fine filter in EDU)	Total Score (stratified by EDU)	Rank
Blue Mountain	Morant River	0.88	2.00	0.5	1.38	1.00
	Wagwater River	0.88	1.00	0.3	1.13	2.00
	Yallahs River	0.63	2.00	0.5	1.13	2.00
	Drivers River	0.75	1.00	0.3	1.00	4.00
	Rio Grande	0.63	1.00	0.3	0.88	5.00
	Hope River	0.88		0.0	0.88	5.00
	Swift River	0.50	1.00	0.3	0.75	7.00
	Spanish River	0.63		0.0	0.63	8.00
	Rio Nuevo	0.50		0.0	0.50	9.00
	Oracabessa - Pagee River	0.50		0.0	0.50	9.00
	Pencar - Buff Bay River	0.50		0.0	0.50	9.00
	Plantain Garden	0.50		0.0	0.50	9.00
Western Limestone	Rio Cobre	1.00	3.00	0.6	1.60	1.00
	Black River	1.00	3.00	0.6	1.60	1.00
	Rio Minho	0.89	3.00	0.6	1.49	3.00
	Rio Bueno-White River	1.00	2.00	0.4	1.40	4.00
	Milk River	0.78	3.00	0.6	1.38	5.00
	Cabarita	0.78	3.00	0.6	1.38	5.00
	South Negril-Orange River	0.78	2.00	0.4	1.18	7.00
	Martha Brae	0.89	1.00	0.2	1.09	8.00
	Deans Valley River	0.67	2.00	0.4	1.07	9.00
	Great River	0.78	1.00	0.2	0.98	10.00
	Montego River	0.78	1.00	0.2	0.98	10.00
	Gut-Alligator Hole	0.67	1.00	0.2	0.87	12.00
	Lucea River	0.67		0.0	0.67	13.00
	New Savannah	0.56		0.0	0.56	14.00

Watershed Prioritisation Calculations: Ecological Integrity

WMU name	Natural Landcover rank	Agriculture rank	Urban rank	Pit Latrine density rank	Sewage/industrial outfalls rank	Water Abstraction Intensity (amt used/amt available) rank	Impoundments rank	Total Score	Rank
Swift River	2	3	3	2.5	1	1	1	14	1
Spanish River	1	6	4	1	1	1	1	15	2
Rio Grande	3	4	2	4.5	8	1	1	24	3
Drivers River	4	7	7	3.5	8	1	1	32	4
Pencar - Buff Bay River	11	8	6	4.5	1	1	1	33	5
Plantain Garden	5	9	1	7.5	1	9	1	34	6
Rio Nuevo	9	11	5	8.5	1	1	1	37	7
Yallahs River	6	2	9	4	8	9	9	47	8
Oracabessa - Pagee River	8	12	10	10.5	1	1	10	53	9
Morant River	7	5	8	9.5	8	9	9	56	10
Wagwater River	12	10	11	7.5	7	1	10	59	11
Hope River	10	1	12	10.5	12	12	1	59	12
Martha Brae	1	1	5	4	5	5	1	22	1
New Savannah	3	13	2	2	1	5	1	27	2
Great River	11	8	8	5	1	2	1	36	3
South Negril-Orange River	4	7	9	3	9	5	1	38	4

WMU name	Natural Landcover rank	Agriculture rank	Urban rank	Pit Latrine density rank	Sewage/industrial outfalls rank	Water Abstraction Intensity (amt used/amt available) rank	Impoundments rank	Total Score	Rank
Rio Bueno-White River	2	9	4	1.5	11	1	12	41	5
Black River	8	3	1	2.5	6	10	10	41	6
Gut-Alligator Hole	10	4	11	3.5	1	12	1	43	7
Cabarita	6	14	7	10.5	1	5	1	45	8
Montego River	5	2	14	11	13	2	1	48	9
Lucea River	13	6	3	12	6	2	11	53	10
Deans Valley River	12	5	12	14	6	5	1	55	11
Rio Minho	7	11	6	9.5	12	12	1	59	12
Rio Cobre	9	10	13	9.5	14	11	13	80	13
Milk River	14	12	10	8	10	12	14	80	14

Watershed Prioritisation Calculations: Conservation Opportunity

EDU	WMU name	Proportion of watershed in NRCA protected areas (rank)	Proportion of watershed in forest reserves (rank)	Proportion of watershed in proposed protected areas (rank)	Total Score*	Rank
Blue Mountain	Rio Grande	1	4	3	9	1
	Spanish River	3	2	6	11	2
	Drivers River	4	7	1	19	3
	Yallahs River	7	3	7	21	4
	Morant River	6	6	4	22	5
	Swift River	2	10	10	22	6
	Hope River	10	1	5	23	7
	Plantain Garden	5	9	2	24	8
	Wagwater River	9	5	8	28	9

	Pencar - Buff Bay River	8	8	9	31	10
	Rio Nuevo	11	11	11	42	11
	Oracabessa - Pagee River	12	12	12	46	12
Western Limestone	Rio Minho	3	4	7	14	1
	Rio Cobre	4	3	6	15	2
	Martha Brae	8	1	4	19	3
	South Negril-Orange River	1	10	10	20	4
	Rio Bueno-White River	10	2	5	25	5
	Cabarita	6	7	9	26	6
	Milk River	7	8	3	27	7
	New Savannah	2	13	13	28	8
	Montego River	9	5	8	28	9
	Lucea River	5	12	12	32	10
	Black River	13	6	1	35	11
	Gut-Alligator Hole	12	9	2	38	12
	Great River	11	11	11	42	13
	Deans Valley River	14	14	14	54	14

APPENDIX 9: JERP Freshwater Review Workshops and Participants

Date	Purpose	Participants
May 19-20, 2003	Introduction to ERP, Selection and review of Freshwater stratification and Targets.	TNC, UWI (DOC, DOLS, DOGG), NEPA, WRA, CCAM, and independent experts
January 16, 2004	Freshwater Viability Analysis	TNC, UWI, NEPA, WRA, and independent experts
March 6th, 2006	Consultation and Review of Draft JERP freshwater results	TNC, WRA
March 9, 2006	Consultation and Review of Draft JERP freshwater results	TNC and Department of Life Sciences (UWI)
March 17, 2006	Consultation and Review of Draft JERP freshwater results	TNC and Forestry Department
March 22, 2006	Consultation and Review of Draft JERP freshwater results	TNC, NEPA (Protected Areas Branch, Biodiversity Branch, Integrated Coastal Zone and Watersheds Branch, Enforcement Branch)
April 21, 2006	Consultation and Review of Draft JERP freshwater results	TNC and EFJ
June 28, 2006	Consultation and Review of Draft Freshwater Gap Assessment	TNC, NEPA (Protected Areas Branch and Integrated Coastal Zone and Watersheds Branch)
August 18, 2006,	Review of Draft JERP freshwater results	TNC and Jamaica National Ramsar Committee
September 21, 2006	Consultation and Review of Draft JERP results	TNC- Jamaica and Global Conservation Action Team (GCAT)

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