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A Proposed Methodology for Surface Water Quality Management for Sustainable Ecotourism in the Caribbean

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Abstract: *Surface water quality's management has political, geographical/institutional, technical and economical issues that need to be considered. The design of a surface water quality management network for the sustainability of the Caribbean's ecotourism necessitates the consideration of all these issues. This paper uses the results of a longitudinal water quality monitoring study at Iwokrama, Guyana and Greencastle Estate, St. Mary, Jamaica to propose a surface water quality management method inclusive of parameters that should be monitored, currently and in the future, as well as options to get monitoring launched in eco-tourism areas throughout the Caribbean. This paper provides information as to cost effective equipment that can be bought such that reliable data can be obtained through partnerships and training of local onsite staff.*

Keywords: *Surface water quality, sustainability, ecotourism, Caribbean*

1. Introduction

Any assessment of water resources mandates mastery of the understanding of both the water quantity and the water quality processes within a watershed (Harmancioglu et al., 1999). The lack of fresh surface water of adequate quantity and quality will make sustainable development impossible (Bartram and Ballance, 1996). For the most part, it is assumed that ecotourism will engage in activities that are sustainable since the fundamentals behind ecotourism include poverty reduction, revenue generation and sustainable development. Various international certifications help to identify tourism destinations with reduced environmental impact, mainly through biodiversity counting and water and energy efficiency audits. Substantial measurements on water quality parameters have not been incorporated into certification procedures and questions remain on the impact of the watershed's ecotourism activities, inclusive of staff, native populations and visitors alike, on surface water quality. Ecotourism facilities throughout the world, inclusive of the Caribbean, are often located in rural and remote areas with limited potable water supply (Eagles et al., 2002) and heavy reliance on harvested rainwater and surface water withdrawals (Manson, 2008). When coupled with the ecosystems services that fresh waterways provide for aquatic flora and fauna it becomes evident that concerns from both the human health and species propagation angles are legitimate (Meybeck et al., 1989; Chapman, 1996). Thus there is a need for region specific water quality monitoring and management that can be sustained both in terms of design and economics. According to Harmancioglu et al. (1999), water quality monitoring comprises all sampling activities to collect and process data on water quality for the purpose of obtaining information about the physical, biological and chemical properties of water.

Two Caribbean eco-tourism sites (Iwokrama, Guyana and Greencastle, Jamaica) were utilised in a 2-year longitudinal water quality monitoring programme. The main objectives with respect to water quality were to develop baseline water quality data at both of the Caribbean study sites with inclusion of ecotourism monitoring and/or management staff so as to be a hands-on training tool for them. Also this work sought to provide a conceptual surface water quality management model can follow to achieve accurate low-cost monitoring. The subtasks to achieve this Caribbean surface water quality management model were:

1) Visit each site and carry out water sampling and in situ monitoring/analyses and ex-situ laboratory analyses,
2) Involve ecotourism management and staff in testing and monitoring exercises onsite, and
3) Use literature and current Caribbean scientific research activities to devise a conceptual path for water quality monitoring and management within the region's ecotourism industry.

This paper focuses on how the suggested surface water quality management and monitoring network was developed in consideration of a 2-year longitudinal water quality monitoring regimen at both sites, as well as staff training for monitoring at both sites.

2. Background

The ecotourism concept dates back to the 1960's when ecologists and environmentalists became concerned over the inappropriate use of natural resources (Fennell, 2003). The preservation of biodiversity was threatened in favor of economic interest and the exploitation of natural resources. According to Higham (2007), the term ecotourism was introduced by Hetzer, an ecologist, in 1965 who also identified its four normative principles. Ecotourism should have minimum environmental impact, minimum impact on – and maximum respect for – host cultures, maximum economic benefits to the host country's grassroots, and maximum recreational satisfaction to participating tourists (Higham, 2007).

The International Ecotourism Society, TIES (2001) offers a succinct and widely accepted definition:

"*Ecotourism is responsible travel to natural areas that conserves the environment and sustains the well-being of local people*."

The World Conservation Union (IUCN) also provides a slightly expanded description of ecotourism's key characteristics:

[Ecotourism is] *environmentally responsible travel and visitation to relatively undisturbed natural areas, in order to enjoy and appreciate nature (and any accompanying cultural features – both past and present) that promotes conservation, has low visitor impact, and provides for beneficially active socio-economic involvement of local populations.* (Brandon, 1996).

There are several different definitions and descriptions of the term ecotourism, but they all are hinged on the underpinnings of Hetzer (1965). What ecotourism should be, according to ideas of sustainability and best practice in development (both of which are contested terrain), does not always coincide with how ecotourism actually operates in reality. The resulting gap between theory and practice is a major source of dissatisfaction with ecotourism-both within the academic world (Cater, 1994, 2004; Duffy, 2002; Ross and Wall, 1999; Whelan, 1991) and within communities and non-governmental organisations (WES, 2002). Despite the issues that persist with sustaining ecotourism globally, the industry continue to thrive with few checks and balances in place to ascertain negative impacts on ecosystems.

Since the 1990s, according to TIES, ecotourism has been growing annually at a rate of 20%-34% on the global scale (TIES, 2001). In 2004, TIES published that ecotourism/nature tourism was expanding 3 times quicker than the entire tourism industry globally. Sun-and-sand tourism is considered to have "matured as a market" and its trajectory is projected to remain a plateau. The converse is true when considering experimental tourism. This form of tourism includes ecotourism, nature, heritage, cultural and soft adventure tourism, as well as other sub-sectors (such as rural and community tourism). Experimental tourism, inclusive of ecotourism, is among the industries projected to grow exponentially over the next two decades. The United Nations Environment Programme (UNEP) and Conservation International (CI) have indicated that most of tourism's expansion is occurring in and around the world's remaining natural areas. Sustainable ecotourism could grow to 25% of the world's travel market within 6 years, taking the value of the sector to US$473.6 billion a year.

The overall steering of global ecotourism is encompassed under the basic mandate of the United Nations' World Tourism Organisation (WTO). The WTO encourages the implementation of the Global Code of Ethics for Tourism, with a view to ensuring that member countries, tourist destinations and businesses maximise the positive economic, social and cultural effects of tourism and fully reap its benefits, while minimising its negative social and environmental impacts. Interesting to note is that Jamaica is a member of the WTO, but Guyana is not. This may be attributed to the sizeable annual membership fees and its nascent tourism industry.

The Caribbean region has traditionally been associated with 'sun, sand and sea' tourism since it is the largest revenue earner for over 10 Caribbean countries and a major foreign exchange earner for most. As such, all Caribbean countries have some governmental Ministry devoted to tourism, inclusive of ecotourism, for the management, marketing and sustainability of the industry on a country basis. Though the WTO has international level support for every member country, the Caribbean Community (CARICOM) created a Caribbean Tourism Organisation (CTO) which provides intellectual support for individual Caribbean member countries on strengthening their tourism products.

2.1. Water and Tourism

Regardless of whether it is conventional sun and sea tourism or ecotourism, the mere presence of tourists places strain on potable water, surface water, and coastal water resources. With the increasing growth of the ecotourism industry globally, inclusive of the Caribbean region, there not just comes increased revenues to countries but also more and more people – and their inherent waste – into some of the world's most pristine and remote areas. These areas of the world, inclusive of their surface waters, are forced to deal with increasing pollutant loadings simply due to presence of the ecotourism industry. This automatically causes a strain on water resources – both in terms of quantity and quality – especially surface water on which several indigenous plants and animals depend, and upon whose survival the ecotourism industry depends. Thus, there needs to be a clear, localised strategy for the Caribbean to deal with managing its surface water quality in ecotourism areas.

2.2 Surface Water Quality Management

The general and widely accepted network model that has been utilised in the planning and management of surface water quality globally is shown in Figure 1. Those steps highlighted are typically done by the site's management, whereas all others can be contracted out or done by site's staff.

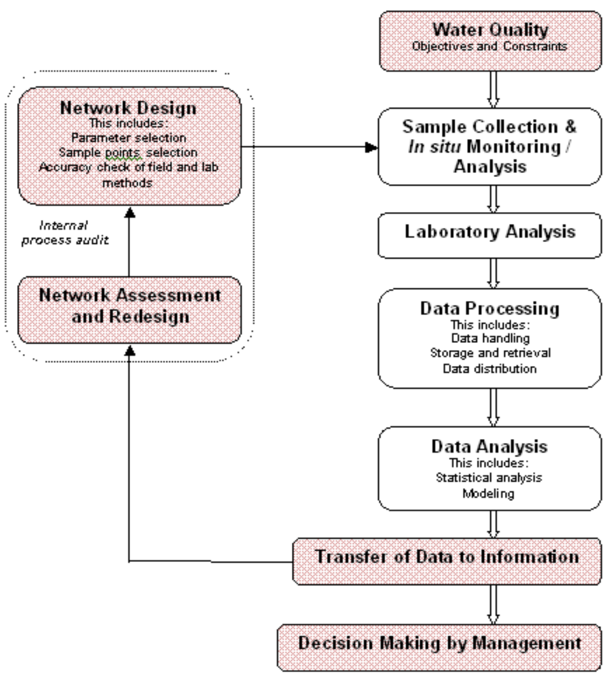


Figure 1. General global water quality management model for natural water resources.
Sources: Adapted from Chapman (1992), Krenkel and Novotny (1980) and Harmancioglu et al. (1999)

According to Ongley (2000), there is no one approach to surface water quality management that is correct for every country or location. However, every contemporary management scheme needs to clearly incorporate design, financing and sustainability considerations that are geographically localised and specific if the management scheme is to be successful. In order to design a specific management programme, there needs to be consideration of (Ongley, 2000):

1) Data objectives – data usually used for government policy and planning so as to meet international set criteria; data that is specific to promotion of public health; regulatory concerns.
2) Efficiency, effectiveness and technical innovation - having a decision support system that places domain knowledge in the hands of local practitioners; use of relatively inexpensive portable field kits, so that large number of analyses can be produced with a high degree of quality control inexpensively.
3) Network design – the creation of community-based groups to assume responsibility for water quality monitoring and management; incorporation of donors for supplies and the quality assurance required to operate the program.

All of these essential considerations are incorporated in this work to attain a proposed method for surface water quality management for the Caribbean's ecotourism industry.

2.3 Study Sites

The two sites chosen for this study were similar, besides both being located within CARICOM; in that they are both young in the ecotourism business and both have desires of implementing water quality monitoring programs. The sites represent the differences that are expected to be found among any Caribbean ecotourism sites. The Guyana site is land-locked, expansive with vast rivers, densely forested, remote and is considered pristine according to Conservation International. The Jamaica site, on the other hand, is much smaller, coastal, rural (but not remote), onsite rivers are very small in length and breadth. The site has a history of non-sustainable onsite farming practices.

The two chosen sites are also in the two geographical extremes within the Caribbean; that is Jamaica is a small island developing state while Guyana, an underdeveloped country, is on the continent of South America. The Jamaica site's ecotourism product is managed by a non-profit non-governmental organisation (NGO) while the Guyana site's ecotourism activities are run by a government affiliated autonomous non-profit body. The intrinsic differences between these two sites (i.e., physical terrain and geography coupled with management structure, historical and present land usage and ecotourism product offerings) encapsulate the myriad of variations that is known to be found at typical ecotourism sites throughout the Caribbean region.

2.3.1 Greencastle Estate, Jamaica

Greencastle estate is a 1,600-acre (6.47 km^2) property on Jamaica's northeast coast between the Blue Mountains and the sea located in the parish of St. Mary. Greencastle Estate offers ridge to coast tourism, making it attractive to the typical ecotourist, the coastal ecotourist and the sun-sea-and-sand tourist.

The Greencastle Tropical Study Center (GTSC) was created in 2005 to develop a dynamic model for Jamaican economic viability through agricultural sustainability, ecotourism, research and education. A saleable ecotourism product has been marketed at Greencastle since 2005. The Center has partnered with The University of the West Indies's Mona, Jamaica campus through the Center for Marine Sciences as well as the Departments of Biology and Ecology to assist with implementation of its surface water quality monitoring. GTSC has also partnered with The University of Minnesota's Department of Fisheries, Wildlife and Conservation Biology and the Department of Sustainable Agriculture to propagate its water monitoring programme.

The fresh water features at Greencastle are comprised of ponds, rivers and a swamp. However, the features are all very small in comparison to the Guyana site. The rivers onsite are on average 0.5 to 2 m wide except where they empty into the sea. Depths are estimated to range from 0.2 to 2.5 m.

2.3.2 Iwokrama, Guyana

This interior region of Guyana, located in Region 8, is 3710 km^2 of forest (1.6% of Guyana's landmass and 2% of Guyana forests). It is managed by the Iwokrama International Center for Rainforest Conservation and Development (IIC) which is a self-autonomous non-profit organisation governed by an international Board of Trustees. IIC was established in 1996 under a joint mandate from the Government of Guyana and the Commonwealth Secretariat to manage the Iwokrama forest.

The Iwokrama forest is drained by the Essequibo River and two smaller rivers, the Burro-Burro and Siparuni, which are briefly confluent before joining the Essequibo. It is bordered to the east by the Essequibo River and to the north and west by the Siparuni River. The Burro-Burro River runs through the central part of the Iwokrama forest. Approximately, 1,500 km^2 of the Iwokrama forest drain directly to the Essequibo River, 1,500 km^2 to the Burro-Burro and 900 km^2 to the Siparuni River (Hawkes and Wall, 1993).

In the vicinity of the Iwokrama forest, the Essequibo River has main channels 250-500 meters wide and is at most approximately 1 km wide (Watkins et al., 2005). It is characterised north of Kurupukari Falls by extensive sand bars that are visible during low water. In several places throughout the Iwokrama forest, it is crossed by volcanic dykes that form rapids. The Essequibo has a probable maximum depth of 40 meters, and its banks are not high except where scouring has occurred (Hawkes and Wall, 1993).

3. Methodology

3.1 Choice of Parameters to Monitor

The decision on which parameters to monitor were made in conjunction with published literature on monitoring needs for surface water based on intended water use as well as cost and practicality factors. The actual sampling sites utilised in the study were chosen to ensure that data were collected throughout the entire watershed. Consideration was given to the practicality of getting to the points during the wet season as well as to the inclusion of input and output flows in the watershed. For the Jamaica site, all watershed input and output flows were sampled while at the Guyana site judgment had to be made to select relevant waterways to be sampled since the entire watershed was too expansive. The chosen sampling locations at the Guyana site particularly focused on the flows into and out of the watershed directly around the main ecotourism activities areas.

Hence, the location selection is considered for the future onsite construction activity that is planned, so that impacts of these additions on water quality can be quantified over a longitudinal monitoring study. It is expected that once monitoring takes place longitudinally changes in land use, population and visitation can be used to correlate with the water quality results once the same sampling points are utilised throughout the longitudinal study of two years. The parameters that were measured along with typical, representative data ranges over the 2-year study period are given in Table 1.

The background concentrations obtained at both sites were matched against the various applicable water quality guidelines of the United States Environmental Protection Agency (USEPA, 2009a, b). The results of the comparison are shown in Tables 2 and 3 for a single point of interest at each site.

The point of interest at Iwokrama was sample point 9 which was at the boat docking area that is typically used for recreational swimming by ecotourists and the main place to embark and disembark boats for river voyages. For Greencastle, the point of interest was taken as sample point 2 which was at the waterfall's pool onsite. This is a point that guests utilise for bathing and relaxation during terrestrial activity such as bird watching.

According to the USEPA (2009a, b) recreational guidelines, the main indicator of quality is the levels of microbial constituents present in the water. Though this work did not quantify all the suggested microbes that can be examined in determining water quality, it is clear from the *E. coli* results that the Iwokrama waters are not fit for recreational use by humans and definitely not as a potable water source without further treatment. This result corroborates with that attained by Rivera et al., (1988) for waters in a tropical rain forest. Since no analysis was done for the *E. coli* at Greencastle no conclusion on adherence to guidelines could be concretized.

Table 1. Comparison of the background water quality data collected at both sites

Parameter	Ranges		Average values	
	Iwokrama	Greencastle	Iwokrama n = 14	Greencastle n = 13
Temperature (^oC)	26 - 28.27	25.61 - 33.05	27.27	28.21
Specific conductivity (mS/cm)	0.014 - 0.024	0.299 - 1.066	0.019	0.768
Dissolved oxygen (mg/L)	7.0 – 10.0	0.9 - 7.8	8.0	4.1
DO (% sat)	81 - 106	10.1 - 89.5	92.78	45.32
pH	5.39 - 6.25	5.99 - 8.22	5.79	7.43
Turbidity (NTU)	13 - 32.2	0.6 - 153	17.11	23.42
Salinity (ppt)	all 0.02	0.31 - 13.9	0.02	4.92
ORP (mV)	31 - 109	ND	80.4	ND
Total alkalinity (mg/L $CaCO_3$)	20 - 80	100 - 542	41.54	296
Caustic alkalinity (mg/L $CaCO_3$)	all 0	0 - 22	0	8.2
Carbonate alkalinity (mg/L $CaCO_3$)	20 - 80	100 - 542	41.54	287.8
Total phosphate conc. (mg/L)	0.298 - 0.477	0.611 - 2.569	0.399	0.923
Polyphosphate conc. (mg/L)	0.178 - 0.447	0.091 - 0.713	0.330	0.483
Orthophosphate conc. (mg/L)	0.030 - 0.119	0.131 - 2.477	0.069	0.539
Nitrate (NO_3^--N) (mg/L)	0 - 3	1 - 15	0.9	8.9
Total hardness (mg/L $CaCO_3$)	40 - 100	40 - 232	55.38	136.89
Ca conc. (mM)	0.2 - 0.6	0.3 – 1.66	0.3	0.8
Mg conc. (mM)	0 - 0.4	0.1 - 0.96	0.2	0.56
COD (mg/L)	0 - 2	2 - 8*	0.6	3.7*
E. coli (CFU/100mL)	100 and 300#	ND	200#	ND
Dissolved Al (ppb)	all <5	all <5	all <5	all <5
Dissolved As (ppb)	all <5	all <5	all <5	all <5
Dissolved Se (ppb)	all <5	all <5	all <5	all <5
Dissolved Pb (ppb)	all <5	all <5	all <5	all <5
Dissolved Cd (ppb)	all <5	all <5	all <5	all <5

Remarks: Values obtained from June 2009 monitoring;
ND - no data; #Based on replicates done only at the point of interest (i.e. Sample point 9 – Dock at Iwokrama)

Source: Adapted from Thomas et al. (2009)

However, from observations of watershed practices it is expected that Greencastle's surface water would not adhere to either the recreational or drinking water guidelines. It is shown in Table 3 that the water at both Iwokrama and Greencastle generally met the criteria to support aquatic life. The chief parameters in this determination are the dissolved oxygen (and its associated parameters such as chemical oxygen demand and percentage of dissolved oxygen saturation), heavy metals and pH. This type of determination is critical to the propagation if ecotourism as at its core is biodiversity.

3.2 Hands-on Staff Training

At each site both upper level management staff as well as middle and lower level staff who are involved in the site's ecotourism management observed and assisted in the field sampling and monitoring inclusive of the selection of sampling points. Their intrinsic knowledge of the lay of their properties gave novel insights on optimum monitoring sites in consideration of practicality to assessing proposed sampling points. This involvement is of particular importance in the adoption of a water quality regimen as diffusion without adoption cannot constitute sustainable practice. The opportunity was also taken to discuss with management what they can do, with or without the ability to do formal water quality monitoring, to reduce pollutant loadings to its surface waters. The discussion hinged on the reduction of stormwater runoff.

3.3 Impact of Stormwater Runoff on Water Quality

It needs to be clear that this study attempts to quantify the impact on water quality of the ecotourism activities of which tourist arrival and departure are subsets; such that ecotourism activities refer to the preparatory anthropogenic activities to allow for desired experiences by guests.

Table 2. Compliance of water quality at point of interest in the surface water to recreational and drinking water guidelines of the United State Environmental Protection Agency

Parameter	Values at point of interest		USEPA guideline values		USEPA guidelines met?			
	Iwokrama (IIC) Sample point 9	Greencastle (GC) Sample point 2	Drinking (Drink.)	Recreation (Rec.)	IIC Drink.	IIC Rec.	GC Drink.	GC Rec.
Temperature (^{o}C)	27.99	25.81	-	20 - 30	NA	Yes	NA	Yes
Specific conductivity (mS/cm)	0.014	0.74	-	-	NA	NA	NA	NA
Dissolved oxygen (mg/L)	7.86	7.84	-	-	NA	NA	NA	NA
DO (% sat)	99.7	89.5	-	-	NA	NA	NA	NA
pH	6.4	7.03	6.5 – 8.5	5.0 – 9.0	No	Yes	Yes	No
Total dissolved solids (g/L)	0	ND	-	-	NA	NA	NA	NA
Turbidity (NTU)	13.2	1.2	<15	<50	Yes	Yes	Yes	Yes
Salinity (ppt)	0.02	4.1	-	-	NA	NA	NA	NA
ORP (mV)	80	ND	-	-	NA	NA	NA	NA
Total alkalinity (mg/L $CaCO_3$)	60	336	-	-	NA	NA	NA	NA
Caustic alkalinity (mg/L $CaCO_3$)	0	0	-	-	NA	NA	NA	NA
Carbonate alkalinity (mg/L $CaCO_3$)	60	336	-	-	NA	NA	NA	NA
Total phosphate conc. (mg/L)	0.417	0.611	-	-	NA	NA	NA	NA
Polyphosphate conc. (mg/L)	0.298	ND	-	-	NA	NA	NA	NA
Orthophosphate conc. (mg/L)	0.119	1.117	-	-	NA	NA	NA	NA
Nitrate (NO_3^--N) (mg/L)	1	6	-	-	NA	NA	NA	NA
Total hardness (mg/L $CaCO_3$)	40	132	-	-	NA	NA	NA	NA
Ca conc. (M)	0.0002	0.0006	-	-	NA	NA	NA	NA
Mg conc. (M)	0.0002	0.00072	-	-	NA	NA	NA	NA
COD (mg/L)	0.1	5.6	-	-	NA	NA	NA	NA
E. coli (CFU/100mL)	200*	ND	0	126	No	No	NA	NA
Dissolved Al (ppb)	<5	<5	50 - 200	50 - 200	Yes	Yes	Yes	Yes
Dissolved As (ppb)	<5	<5	<10	<10	Yes	Yes	Yes	Yes
Dissolved Se (ppb)	<5	<5	<10	<10	Yes	Yes	Yes	Yes
Dissolved Pb (ppb)	<5	<5	<10	<10	Yes	Yes	Yes	Yes
Dissolved Cd (ppb)	<5	<5	<5	<5	Yes	Yes	Yes	Yes

Remarks: Based on replicates done only at the point of interest (i.e. Sample point 9 – Dock at Iwokrama);
ND – no data; NA – not applicable

Source: Based on USEPA (2009a, b).

In order to see the direct impact of the presence of tourists there would be comparison of data during times of no or low tourist arrivals to that of peak tourist flow. This depends on the assumed equity ratio of supply and demand, which the study subliminally tests whether pollutant loadings are unaffected by the presence of tourists, who can be modeled as transitory populations.

However, it is possible that stormwater runoff can have a more disastrous impact than the presence of tourists on surface water quality. The impact of this stormwater is highly contingent upon the amount of impervious surface there is onsite, the slope where the impervious surfaces are constructed as well as grey water disposal techniques of households within the watershed (Pegram and Bath, 1995). The ecosite's management has the ability to influence all 3 of these areas through better onsite planning and community participation in design and construction of more sustainable water disposal methods.

Table 3. Typical compliance of water quality data check at a point of interest in the surface water to aquatic organisms water guidelines of the United State Environmental Protection Agency

Parameter	Values at point of interest		USEPA Aquatic Organisms guideline values		USEPA guidelines met?			
	Iwokrama (IIC) Sample point 9	Greencastle (GC) Sample point 2	Acute	Chronic	Acute (IIC)	Chronic (IIC)	Acute (GC)	Chronic (GC)
Temperature (^oC)	27.99	25.81	Species dependant		NA	NA	NA	NA
Specific conductivity (mS/cm)	0.014	0.74	-	-	NA	NA	NA	NA
Dissolved oxygen (mg/L)	7.86	7.84	3.0	5.0	Yes	Yes	Yes	Yes
DO (% sat)	99.7	89.5	85	85	Yes	Yes	Yes	Yes
pH	6.4	7.03	-	6.5-9	NA	No	NA	Yes
Total dissolved solids (g/L)	0	ND	-	0.25	NA	Yes	NA	ND
Turbidity (NTU)	13.2	1.2	10% above seasonal norm		NA	NA	NA	NA
Salinity (ppt)	0.02	4.1	0.25	0.25	Yes	Yes	No	No
ORP (mV)	80	ND	-	-	NA	NA	NA	NA
Total alkalinity (mg/L $CaCO_3$)	60	336	-	200	NA	Yes	NA	No
Caustic alkalinity (mg/L $CaCO_3$)	0	0	-	200	NA	Yes	NA	Yes
Carbonate alkalinity (mg/L $CaCO_3$)	60	336	-	200	NA	Yes	NA	No
Total phosphate conc. (mg/L)	0.417	0.611	-	0.1	No	No	No	No
Polyphosphate conc. (mg/L)	0.298	ND	-	-	NA	NA	NA	NA
Orthophosphate conc. (mg/L)	0.119	1.117	-	-	NA	NA	NA	NA
Nitrate (NO_3^--N) (mg/L)	1	6	-	10	NA	Yes	NA	Yes
Total hardness (mg/L $CaCO_3$)	40	132	-	300	NA	Yes	NA	Yes
Ca conc. (M)	0.0002	0.0006	-	-	NA	NA	NA	NA
Mg conc. (M)	0.0002	0.00072	-	-	NA	NA	NA	NA
COD (mg/L)	0.1	5.6	5	5	Yes	Yes	No	No
E. coli (CFU/100mL)	200*	ND	126	-	Yes	NA	ND	NA
Dissolved Al (ppb)	<5	<5	750	87	Yes	Yes	Yes	Yes
Dissolved As (ppb)	<5	<5	340	150	Yes	Yes	Yes	Yes
Dissolved Se (ppb)	<5	<5	-	5	NA	Yes	NA	Yes
Dissolved Pb (ppb)	<5	<5	65	2.5	Yes	Yes	Yes	Yes
Dissolved Cd (ppb)	<5	<5	2	0.25	ND	ND	ND	ND

Remarks: Based on replicates done only at the point of interest (i.e. Sample point 9 – Dock at Iwokrama); ND – no data; NA – not applicable

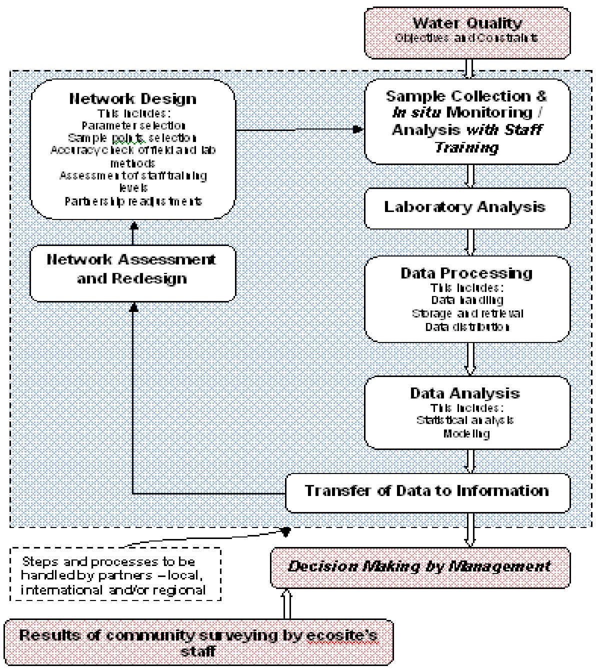
Source: Based on USEPA (2009a)

4. Results

4.1 Impact of Hands-on Staff Training

At both sites some staff was trained in conducting in situ water quality monitoring and sampling during the first visit to initiate the longitudinal study. Employees at various levels were involved in the training. At Greencastle, two upper level managers were trained along with 1 middle level and one lower level manager. Though only 4 persons were trained this represented 50% of all onsite full time staff at Greencastle at the time. Similarly, some 15 staff members were trained at Iwokrama (1 upper level manager, 3 middle level managers, 4 lower level managers and 7 rangers). This represented only 24% of all onsite full-time staff at Iwokrama at the time. The training at both Iwokrama and Greencastle resulted in data collection and water sampling during the baseline data collection period. Thus, involvement of the local through training allowed for sustaining the water quality monitoring programme. Both sites are continuing with their regular data collection today.

Figure 2 depicts a proposed conceptual water quality management model for surface waters in and around ecotourism sites in the Caribbean. The key step is partnership to carry out the analytical and onsite water quality work and staff training in field methods and techniques. As a first approach, this is suggested in consideration that most ecotourism operations in the Caribbean typically do not have the funds or skills required to design and implement a rigorous and dynamic water quality monitoring scheme. Partnerships can be at the local, regional or international level.



Remarks: Highlighted steps are typically done by the site's management, and all others are to be carried out to partners.

Figure 2. A proposed conceptual water quality management model for surface waters in and around ecotourism sites in the Caribbean

Local partnerships are the best option (i.e. most sustainable option) for the sampling, monitoring and analysis of samples as this is where the bulk of the cost will lie in the scheme. For regional and international partners, the transportation of supplies to the site and water samples to their laboratories is not very feasible especially for time sensitive tests. As such local partnerships with universities, schools and volunteer organisations can be a good start to collecting valuable data. Volunteer organisations, especially those with an environmental protection mandate, could be capitalised upon such that they can operate similarly to the Adopt-A-Pond Programme works in Florida (Hillsborough, 2011).

Senior classes in high school have projects that can utilise the ecosites as the study areas where applicable. Though the Caribbean's universities still remain mainly teaching driven, there are a few researchers within the university structure that have interest in tourism and ecotourism. Once sought after, potential partnerships can be done for detailed water quality studies to be entered into as student projects at the undergraduate or graduate level.

Though less feasible, similar arrangements can be entered into with regional and international universities where their students do international research at various ecotourism sites. This can be done as a part of study abroad offerings for undergraduates through their colleges and universities. Local, international and regional partnerships can be entered into through the funding of proposals for water quality management studies written by collaborators. Though grant facilitation is not the norm for funding in the Caribbean, it can be exploited to gain funds from large international corporations and agencies (e.g. Ford Motors, United Nations Environment Programme, and the World Bank etc.) that annually fund projects that promote sustainable development in the developing world.

Regionally, several academic, public and professionals-based organisations lend their skills for the development of Caribbean science including the CTO, the Caribbean Academy of Science (CAS) and CariScience. These entities have regional and international partners that they match to projects of similar interests without cost. Spokespersons for CTO said that any person with a tourism project ongoing within a territory of CARICOM is eligible to be assisted in proper planning of their activities. However, this service is highly under-utilised often due to the misconception of the associated costs.

Jackson (2000) argues that by the application of partners to a water quality monitoring/management project in consideration of communities' survey responses allows for a systems approach to management. The ecotourism site would be responsible for determining changes in the water loadings of its surrounding communities (van Veelen and van Zyl, 1995). This should be considered as part of its final management decisions. The other major aspect of the conceptual model is that partners train staff members in the water quality monitoring and sampling, so as to continue to build the self-sufficiency of the personnel on site to do accurate water quality work.

4.3 Parameter Selection in Designing the Monitoring Network

The world rigorous water quality monitoring programmes (such as the United Nations Environmental Programme GEM/WATER programme and the Florida Water Atlas Project) routinely disseminate data on comprehensive water quality testing collected by various entities including volunteer organisations (United Nations, 2008). The parameters reported in these types of programmes are water discharge/head, total suspended solids, transparency, temperature, pH, conductivity, dissolved oxygen (including Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)), calcium, magnesium, sodium, potassium, chloride, sulfate, alkalinity, nitrate plus nitrite, total phosphorus (unfiltered), total phosphorus (dissolved), fecal coliform, reactive silica, heavy metals (cadmium, selenium, lead, mercury, iron, arsenic) and chlorophyll A (Turner II et al., 1995; UNEP, 2009).

The selection of water quality parameters for the ecotourism industry in the Caribbean needs to be calculated in consideration of background monitoring data, water body usage, cost, USEPA aquatic life/organisms and recreational water quality guidelines and generally accepted water quality monitoring programme requirements (Lo et al., 1996; Somlyody et al., 1994; Ongley, 1998).

According to Ongley (1999), when considering development of a monitoring network for the developing world there is need to understand the dynamics of the people in a given watershed in terms of their present, past and future avenues of environmental pollution. Due to the lack of data this type of social input is required in for selection of monitoring needs of today and tomorrow (Ongley, 1997). Thus the social data collected in this study (from researcher observation, the community survey, interview of management and staff, screening and scoping exercise and the checklist) was factored into the analysis to choose essential water quality parameters to be monitored.

Given the aforementioned criteria, the following parameters can be suggested for inclusion in a regular water quality monitoring schedule: BOD, COD, pH, temperature, dissolved oxygen (DO), dissolved oxygen saturated (DO%sat), total dissolved solids (TDS), NO_3^--N, total phosphate, specific conductivity (SpC)/salinity, fecal coliform, heavy metals (lead, arsenic, cadmium, selenium, aluminum, nickel, mercury and zinc) and stream flow rate. Table 4 presents the costs associated with carrying out most of the suggested water quality tests. Costs are from Fisher Scientific™.

Table 4. Cost and ordering details for implementing on site ecotourism water quality monitoring programme in the Caribbean

Parameter	Required materials and/or equipment	Manufacturer and catalog numbers	June 2011 cost* (US$)
pH, temperature, total dissolved solids (TDS)/salinity/specific conductivity, turbidity, dissolved oxygen (DO), DO% saturation	Quanta Hydrolab™ multimeter	Hach® (014710HY; 014730HY; 005200 ; 004484; 004452; 004507HY)	3,605.00
pH	pH 4, 7 and 10 buffers solutions	Fisher Scientific™ (SB101-4, SB115-4, SB107-4)	319.38
Turbidity	10 NTU and 40 NTU standards	40 NTU: Hach® (2746353); 10 NTU: Ricca Chemicals® (R8801000-4C)	230.99
Total dissolved solids (TDS)/salinity/specific conductivity	500 μΩ/cm, 445 μΩ/cm and 200 μΩ/cm conductivity/TDS standards	Ricca Chemicals® (2249.20-32; 5887.5-32; 2240.45-32)	136.60
Fecal coliform/*E. coli*	Colilert-18 for 100 ml; 120ml vessel w/ 100ml line, sodium thio & shrink band; 100-pack sterile 97-Well Quanti-Tray; Colilert/Colilert-18 Comparator predispensed in a Quanti-Tray; 4 watt pocket UV lamp; One pair UV absorbing Goggles	IDEXX Laboratories® (WP200I-18; WV120SBST-200; WQT-2K; WQT2KC; WLG)	1336.43
Alkalinity	One burette; 0.02 N sulfuric acid; beakers; phenolphthalein indicator; methyl orange indicator	Fisher Scientific™ (Acid: SA226-4; Burette and beakers: 03-700B; FB-102-200; Methyl orange: SM54-500; Phenolphthalein: SP62-1)	241.24
Nitrate-Nitrogen	Test N' Tube kit; portable spectrophotometer	Hach® (2605345; DR2700-01#)	2,579.25
Phosphate-phosphorus	Test N' Tube kit; portable spectrophotometer	Hach® (2742645; DR2700-01#)	65.64
COD	Test N' Tube kit; COD reactor; portable spectrophotometer	Hach® (2125825; LTV082.53.40001; DR2700-01#)	916.00
BOD	BOD incubator; BOD meter; BOD chemical kit; BOD nutrient buffer pillows; BOD bottles	Hach® (8505700; 1416066; 1486510; 2616200; 2943100)	4,182.53
Sampling and washing	HDPE sampling containers; one acid and one base reservoir; conc. nitric acid, sodium hydroxide pellets	Fisher Scientific™ (A200-212; S320-500; 02-896-2F; 14-831-330A)	593.61
Stream flow	Flowmeter	Hach® (MODEL_2000-11)	3,713.00

Remarks: *Cost is devoid of taxes and shipping charges;
Cost of portable spectrophotometer only included with Nitrate-Nitrogen as the same instrument is use for these parameters.

The chosen materials are based on field appropriate USEPA approved and/or standard methods and equipment that are the most economically priced without compromising detection quality. It is noted that details are not provided for heavy metal analysis since commercially available field kits do not have the detection limit in the parts per billion range as expected based on the background monitoring data.

Where a site is able to do most of water quality testing on its own, it is envisioned that partnership will be needed for both the heavy metal testing and the analysis of all collected data. Trend analysis is the most typical method used to analyse a watershed's surface water quality (Chang, 2008). This method involves collecting water quality data on a regular basis (typically monthly) for a minimum of two years and comparing data per parameter over time. This data is then analysed through multivariate statistical techniques including cluster analysis, factor analysis, principal component analysis and discriminant analysis (Bargos et al., 1990; Ouyang, 2005; Singh et al., 2004) to inform which parameters are significant enough to warrant further investigation through monitoring.

4.4 Emergent Chemicals of Concern for Future Monitoring and Management

The chemicals of concern are those associated with pharmaceuticals and personal care products inclusive of steroids. Pharmaceuticals can be used internally or externally by humans and domestic animals and include all drugs available by prescription or over-the-counter. According to Daughton (2001), many of these compounds are highly bioactive and usually occur at trace concentrations when present in the environment. Once in the environment, generally the drugs are absorbed by the organism and are subjected to metabolic reactions of the body. However, a significant amount will leave the organism unmetabolised via urine or feces and will end up in sewage or manure (Hirsch et al., 1999).

Some of the most popular chemicals of concern, due to their endocrine disrupting properties, are caffeine ($C_6H_{10}O_2N_4$), DEET (N,N-diethyl-meta-toluamide ($C_{12}H_{17}NO$)), bisphenol A ($C_{15}H_{16}O_2$) and β-estradiol ($C_{18}H_{24}O_2$). These are of concern due to their global use, presence and potential harm to aquatic life. Thus it is suggested that these analytes be added to surface water quality programmes as soon as practical 1,3,7-trimethylxantine (i.e. caffeine) is one of the most widely consumed global drugs with the global average consumption of about 70 mg per person per day. The major source of caffeine in domestic wastewater comes from unconsumed coffee, tea, sodas, or discarded medication. Therefore, caffeine can be highly persistent in the aquatic environment. DEET is commonly found as an active ingredient in many insect repellent products. DEET is registered for human use only in the concentration range of 4 to 100% DEET for direct skin contact.

Similarly, bisphenol A is another endocrine disruptor used industrially for polycarbonate plastic and epoxy resins. This type of plastic and resin is widely applied to the production of digital media, medical equipment and items as well as vision lenses. Effluents from facilities that manufacture epoxy and polycarbonate plastics and elution from the products containing it are suspected to be the major source of this contaminant in the environment (Suzuki, 2004).

In the case of β-estradiol, it is traditionally known to be excreted through feces and released from sewage treatment plants after treatment in their effluent and according to Barel-Cohen et al. (2006), it is one of the most potent endocrine disrupting compounds. The advent of synthetic hormones in several oral contraceptives studies has shown their prevalence even in grey water (Jobling et al., 2006). In the Caribbean areas chosen for study, there is known to be no sewer network and most dwellings are either using outdoor pit latrines or indoor toilets on a septic tank–soak away system.

Many researchers (e.g., Lee et al. (2004), Harries et al. (1997), and Jobling et al. (2006)) corroborated that DEET has immense potential to have endocrine disrupting effects on wildlife. Further to this, DEET is the most common active ingredient in insect repellents (Lee et al., 2004), a product expected to be in use by eco-tourists. It is for this reason that it has been included into the contamination analysis. For instance, Brazil is now mandating the permissible concentrations of DEET in visitors' insect repellents in certain parts of their rainforest in lieu of the above (Trotz, 2007). Further, the monitoring of these and similar compounds generally require the use of gas chromatography with mass spectroscopy (CG-MS). Most of the methods are currently being tested and developed for standardisation.

5. Conclusion

By visiting each of the two sites and conducting a 2-year longitudinal monitoring scheme, background concentrations for various water quality parameters of concern in the natural environment were attained, while simultaneously training ecotourism staff was made on water quality management methods and considerations. One important consideration dealt with was that of stormwater runoff and areas that management needs to focus on to reduce its pollutant loading effect.

In order to solidify the importance of ecotourism's management on surface water quality, a conceptual path was suggested in consideration of the state of the industry in the Caribbean. The main thrust was for the inclusion of partners (local, regional and international) to assist with water quality management, data analysis and simultaneous training of staff. Compounds that would most likely be of future water quality concern are also highlighted along with suggested pricing and part numbers for relevant tests that should be implemented now at ecotourism sites.

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