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# *The characterization and classification of the Black River Upper Morass, Jamaica, using the three-parameter test of vegetation, soils and hydrology*

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## ABSTRACT

1. The characterization and classification of the Black River Upper Morass was conducted using the criteria of the three-parameter test for vegetation, soils and hydrology at 14 sites within the study area.

2. The Upper Morass exhibited 71% hydrophytic vegetation typical of wetlands (vascular and non-vascular plants including *Cladium jamaicense*, *Phragmites australis*, *Typha angustifolia* and *Sagittaria lancifolia*) and 29% vegetation atypical of wetlands.

3. The Upper Morass is classified as a Palustrine System with sub-classes of Aquatic Bed and Persistent Emergent Wetland.

4. The presence throughout the Upper Morass of monoculture stands of the invasive species *Eichhornia crassipes* and *Typha domingensis*, which are known to invade disturbed or partially drained wetlands, confirmed that the study area was a disturbed ecosystem.

5. The Upper Morass exhibited hydric (flood-water and groundwater) soils, which, in association with its temporarily flooded and saturated wetland hydrology, indicated that it is groundwater-driven.

6. Application of the three-parameter test indicated a linkage between the functions of the Upper Morass and the Lower Morass, and thus a need for conservation of the Black River Morass System as a single unit rather than two independent wetlands. Two key instruments of conservation will be further detailed ecological assessments and the implementation of a management plan.


KEY WORDS: wetland; freshwater; hydrophytic; hydric; invasive species; conservation; ecological assessment; management

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## INTRODUCTION

The Black River Morass is one of Jamaica's larger wetlands and is situated on the south-western coast of the island in the parish of St. Elizabeth (Figure 1). It has been described as the most important of wetlands that cover 2% of Jamaica's surface area (Garrick, 1986). It consists of two distinct parts, the Black River Upper Morass (1762 ha (4350 acres)) and the Black River Lower Morass (6075 ha (15 000 acres)) (Grontmij, 1964). Both are ecologically significant freshwater wetlands at a local and international level, providing habitat for endemic, endangered and threatened species, including *Crocodylus acutus* (American crocodile) (Vulnerable — IUCN Red List of Threatened Species and CITES Appendix I species) and *Dendrocygna arborea* (West Indian whistling duck) (Vulnerable — IUCN Red List of Threatened Species and CITES Appendix II species); nurseries to marine shrimp and fish species and genetic reserves for flowering plants.

Following extensive studies of the Lower Morass, in 1997 this wetland was nominated and later designated under the Ramsar Convention on Wetlands of International Importance (October 7, 1997; Wetland International Site #6JM001). The Upper Morass is smaller than, and intimately linked to, the Lower Morass. It is an inland wetland owing to its geographical location and topography, and is surrounded by small rural communities. It has Game Reserve Protected Status (The Wild Life Protection (Amendment of First Schedule) Order, 1997), and little or no scientific research has been conducted within the area. Documented research and projects for the Upper Morass were mainly agricultural (Grontmij, 1964; Harza Overseas Engineering Company (HOEC), 1976; Hudson, 1983; Government of Jamaica, 1985;

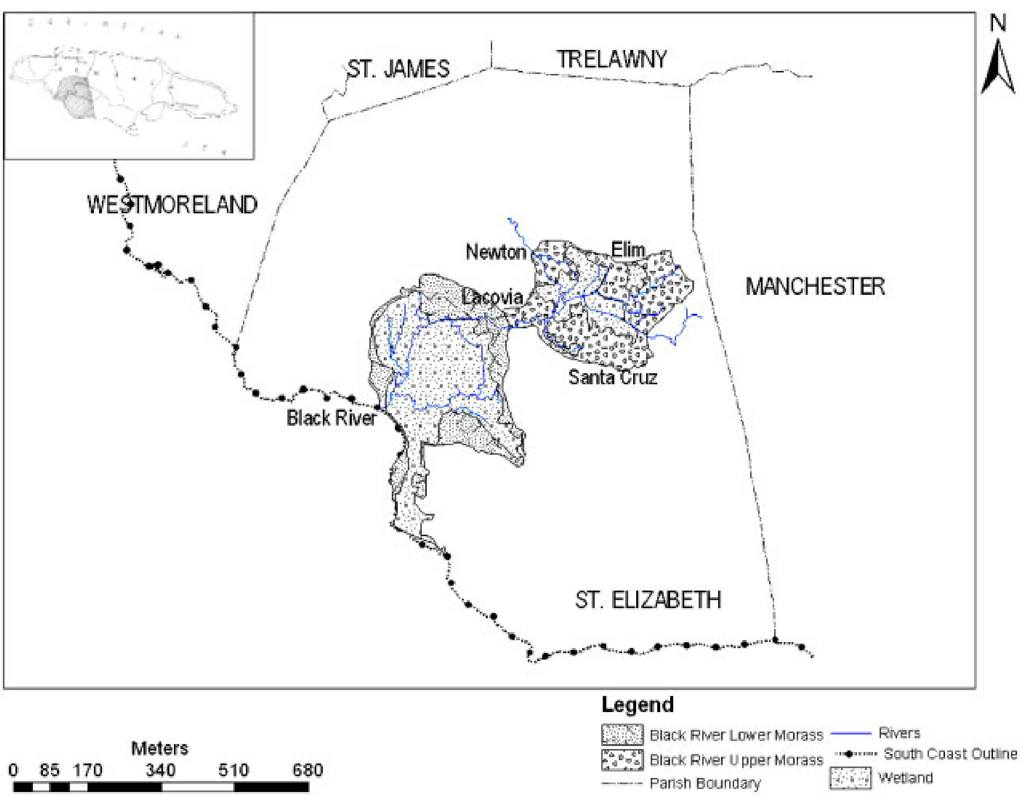


Figure 1. Layout of the Black River Morass System.

 

Massa and Haynes-Sutton, 1998) with few studies on biodiversity (Proctor, 1964; Harza Overseas Engineering Company (HOEC), 1976; Haynes-Sutton, 1998; Haynes-Sutton and Hay, 2002).

Reclamation of the Upper Morass commenced in the 1960s with the hope of establishing a viable rice production industry in Jamaica; however, these plans were not implemented. In 1976, HOEC was commissioned to determine the possible uses of the Upper Morass after reclamation. HOEC, using the US Bureau Reclamation Classification as well as the topography and physical characteristics of the site, classified the soils in different sections of the Upper Morass as being suited for irrigation farming, general cultivation, pasture or shallow-rooted vegetation and non-cultivatable.

Prior to the dyking of the Upper Morass and the construction and commission into service of the Holland Pumping Stations in the 1980s, the Upper Morass functioned as a major flood reservoir during peak flows of the Black River (Government of Jamaica, 1985). Subsequently, the flood magnitudes in the Upper Morass (the Black River and associated tributaries) were reduced by the regulating effect of the dykes and the Pumping Station resulting in significantly smaller peak discharges downstream into the Lower Morass. Following the closure of the rice fields (late 1980s), the pumping stations were decommissioned and outflow from the Upper Morass was facilitated by culverts and by cutting the dyke in sections (Government of Jamaica, 1985). Consequently, the Upper Morass was left idle.

The present study seeks to characterize and classify the Black River Upper Morass using the criteria listed for the three-parameter test, which constitutes vegetation, soils and hydrology as reported by Tiner (1993). This method enables the identification and delineation of the wetland, its components, and areas requiring protection and/or management.

## SITE DESCRIPTION

The Upper Morass borders the Black River from Newton to Lacovia, and stretches from Santa Cruz in the south to the Elim Estate area in the north. It lies in an almost circular valley and is drained by several tributaries of the Black River, North Elim, South Elim, Foster, Braes, Mount De las Uvas, New and Island Rivers. The Upper Morass is covered with varying types of vegetation, herbs, shrubs, trees and agricultural crops (Figure 2).

## METHODS

Fourteen sites were chosen after detailed photogrammetric analysis was conducted prior to sampling, with reference to data for 1976, 1987, 1991 and 1999. Site selection was based on the vast acreage of the Upper Morass, the total area of wetland demarcated, the areas of disturbance identified and its history of reclamation (Figure 3). The vegetation, soils and hydrology at each site were investigated using adaptation of methods prescribed for the US Army Corps three-parameter test (Tiner, 1993), as described below.

### Vegetation

The vegetation of the Upper Morass was surveyed in the year 2000 for 6 months, of which three were in the dry season (January, February and March) and the other three in the wet season (May, August and October). The vegetation at each sampling site was assessed on the basis of six observations at 20-m intervals along a 100-m transect (commencing at zero). Plant species were recorded by stratum (e.g. tree, shrub, herb) and for each species, the abundance (DAFOR scale; D = dominant, A = abundant, F = frequent, O = occasional, R = rare) and percentage cover was estimated. Dominants were identified by

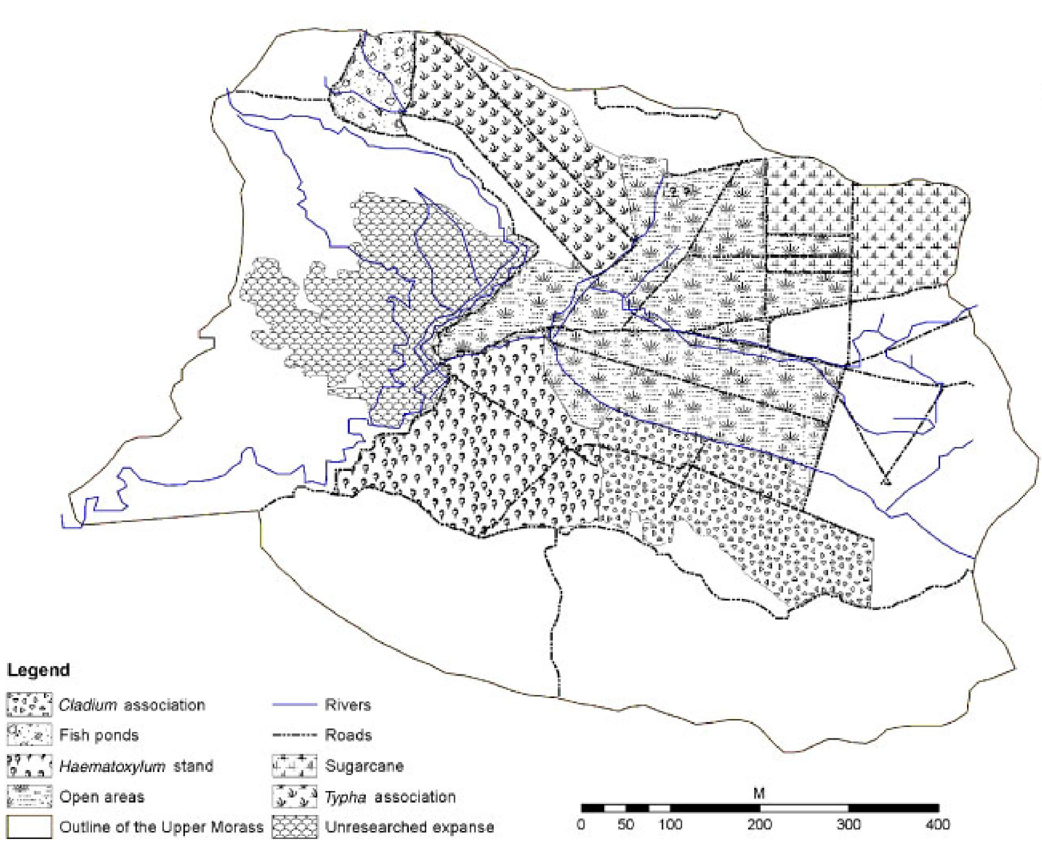


Figure 2. Vegetation recorded for the Black River Upper Morass.

applying the 50/20 dominance rule. The dominant species of each stratum is determined by calculating which single species makes up more than 50% and more than 20% of the total cover.

The vegetation recorded at each site was classed as hydrophytic: 'macrophytic plant life growing in water (permanently inundated areas) or in areas subject to periodic flooding or permanent or periodic saturation near the soil surface and at least periodically deficient in oxygen due to excessive water' (Tiner, 1993), or non-hydrophytic according to the criteria set out by Tiner (1993). On this basis, the vegetation was classified as hydrophytic if more than 50% of the dominant species in the plant community had an indicator status of obligate wetland (OBL), facultative wetland (FACW) or facultative (FAC); or if two or more of the dominant species exhibited one or more of the following characteristics:

- morphological adaptations to wetland hydrology;
- were known to be physiologically adapted for life in saturated soils;
- were known to have reproductive adaptations for life in wetlands;
- were cited in literature as species common to wetlands;
- were actually observed growing in areas of prolonged inundation and/or soil saturation.

The determination of whether more than 50% of the dominant plant species exhibited a wetland indicator status of OBL, FACW, FAC or UPL ('obligate upland plants which occur almost always under natural conditions in non-wetlands'), was achieved using the PLANTS Database (USDA, NRCS, 2001).

 

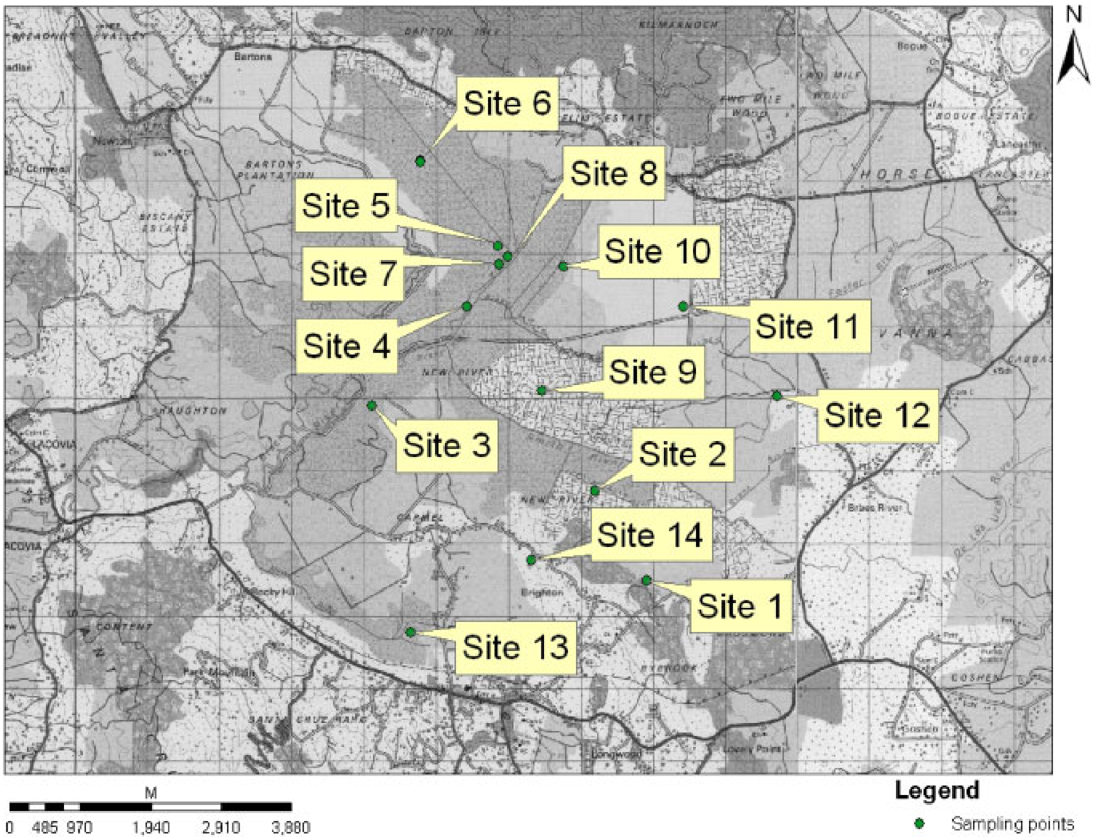


Figure 3. General layout and location of sample sites within the Black River Upper Morass.

Morphological adaptations of leaves, root structure and growth habit were determined visually in the field, where possible, and in the laboratory. In addition, samples of root and stem material were preserved in 10% alcohol after which sections were prepared and examined under a microscope.

### Soils

The presence of hydric soils was assessed on the basis of the criteria set out by Tiner (1993) for non-sandy soils:

- organic soils;
- histic epipedons (organic surface layers usually 20–41 cm (8–16 inches) thick;
- sulfidic material (odour);
- aquic or peraquic moisture regime (permanent or periodic reducing environment). A reducing regime is virtually free of dissolved oxygen because the soil is saturated by groundwater or by water of the capillary fringe;
- observed reducing conditions;
- soil colours;
- soil listed as a hydric soil;
- iron and manganese concretions within 7.6 cm (3 inches) of the soil surface;

 

and for sandy soils:

- high organic matter content in the surface layer;
- organic streaking in the subsoil.

The soil was collected immediately below the A-horizon using a Ponar Inner-Liner soil core, midway along the 100-m transect used for the vegetation assessment. The soils from each site, 14 in total, were extracted from the core liners in the laboratory and weighed, after which they were divided into three portions for tests on water content by weight, loss on ignition (organic matter) and soil porosity.

### *Water content by weight*

The water content by weight is the weight of water in the soil relative to the weight of the solid matter and was used to determine the sites within the Upper Morass that had a high percentage value for soil saturation. The analysis was done in replicates and involved weighing 50 g ($W_1$) of soil, which was subsequently dried to a constant weight ($W_2$) at 105°C. The water content by weight was calculated using the formula:

$$\frac{W_1 - W_2}{W_1} \times 100$$

### *Loss on ignition*

The percentage weight of soil lost on ignition indicates the organic matter (by weight) in the soil. This method involved measuring 10 g ($W_1$) of 2-mm sieved, oven-dried soils in boats of known weight, which were subsequently heated in a muffle furnace for 3 h at 300°C (samples done in replicates). The cooled boats were weighed ($W_2$) and the percentage weight loss calculated using the formula:

$$\frac{W_1 - W_2}{W_1} \times 100$$

The data for water content by weight and loss on ignition exhibited a normal distribution for use in non-parametric tests, and as such, the results was statistically analysed using analysis of variance (ANOVA) and cluster analysis to determine similarity between the sites and their groupings.

### *Soil porosity*

The percentage of sand, silt or clay in a soil determines its characteristics. This method involves the use of a Bouyoucos hydrometer, which determines the weight of soil particles dispersed in a solution and operates on the premise that larger particles in solution sink faster than smaller ones. Fifty grams of dried, sieved 1-mm soil ($W_1$) was placed in a 250-mL beaker to which 12.5 mL of 5% Calgon solution and 150 mL of distilled water was added and the mixture stirred. The solution was transferred to a mixer and dispensed for 10 min, after which it was poured into a 500-mL graduated cylinder and made up to volume using distilled water. The mixture was left to stand for 40 s. Subsequently, a reading was taken using the hydrometer, which determined the weight of silt and clay dispersed in the solution ($W_2$). Two hours later, another reading was taken using the hydrometer, which measured the weight of clay in the solution ($W_3$). The difference in the amount of particles present in the soil sample was calculated and the results converted to percentages.

### Hydrology

The presence of hydrological conditions within the Upper Morass was assessed on the basis of the criteria set out by Tiner (1993) of which two or more secondary indicators are required to verify wetland hydrology. Primary indicators:

- recorded data;
- visual observations of inundation and/or soil saturation. A soil is considered saturated within a minimum of 1 ft (30 cm) of the soil surface for 2 weeks or more about every other year on average (Tiner, 1999);
- water marks;
- drift lines;
- sediment deposits;
- wetland drainage patterns.

Secondary indicators:

- oxidized root channels in the upper 30.5 cm;
- water-stained leaves;
- local soil survey data;
- FAC neutral test.

During the dry season, hydrological conditions within the Upper Morass (presence of primary and secondary indicators) were assessed concurrently with vegetation assessment and soil collection. In the wet season, owing to inaccessibility of the study site, hydrological conditions were observed aerially using a Cessna-172 and 182, flying at an altitude of 800 ft (244 m). Areas of inundation, saturation or 'dry' were plotted on a map of the Upper Morass, which in turn was used to generate maps of hydrological conditions.

## RESULTS

### Vegetation

The Black River Upper Morass consisted primarily of hydrophytic vegetation, of which >50% of the dominant species in the plant community had an indicator status of obligate wetland (OBL) (14 sites), facultative wetland (FACW) (3 sites) and facultative (FAC) (12 sites) (Table 1). In addition, the vegetation dominantly exhibited morphological adaptations to wetland hydrology in the stem and root system of the plants (Table 2), satisfied literature citations of species common to wetlands, and was observed growing in areas of prolonged inundation and/or soil saturation.

### Soil

Soils collected within the Black River Upper Morass exhibited mineral soils (8 of 14 sites), sulfidic material (evident by hydrogen sulphide odour) (14 sites) and aquic/peraquic regime (14 sites). Comparison of the means between sites for organic matter showed that all were significantly different ($p < 0.05$). The highest percentage of organic matter was exhibited by site 1 and the lowest by site 12. The remaining sites exhibited a decreasing percentage of organic matter in no discernible pattern (Figure 4). Application of the cluster analysis revealed that the sites were statistically similar forming four groupings reflecting the trend of decreasing percentage values in organic matter: group A, sites 8 and 12; group B, sites 2, 3, 4, 7 and 9; group C, 5, 11, 13 and 14; and group D, sites 1, 6 and 10 (Figure 5).

 

Table 1. Summary of vegetation assessment conducted within the Black River Upper Morass showing the dominant species identified with their associated stratum and wetland indicator status

| Stratum | Wetland indicator status | Dominant species | Sites 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tree | OBL | *Calyptronoma occidentalis* | | | | | | | | | | | | | | × |
| | FACW | *Sabal jamaicensis* | | | | | | | | | × | | | | | |
| | FAC | *Psidium guajava* | × | | | × | × | | | × | | | | | | |
| | | *Haematoxylum campechianum* | | | × | | | | | | | | | × | | |
| Shrub | FAC | *Euphorbia* sp. | | × | | | | | | | | | | | | |
| | FAC+ | *Eupatorium odoratum* | × | × | | | | | | | | | | | | |
| Herb | OBL | *Cladium jamaicense* | × | × | | | | | | | | | | × | | |
| | | *Hydrocotyle umbellata* | × | | | | × | | | | | | | | | |
| | | *Sagittaria lancifolia* | × | | | | × | × | | | | | | | × | |
| | | *Typha domingensis* | | | × | | × | | × | × | | | | × | | |
| | | *Eichhornia crassipes* | | | × | × | | | | | | | × | | | |
| | | *Dieffenbachia seguine* | | | | | | | | | | | | | | × |
| | FACW | *Gynerium sagittatum* | | | | | | | | | | | | | × | |
| | FACW+ | *Polygonum punctatum* | | | | | | | | | | | | | × | |
| | FAC | *Malachra alceifolia* | | | | × | | | × | | | | | | | |
| | | *Solanum campechiense* | | | | | | | × | | | × | × | | | |
| | FAC+ | *Lippia strigulosa* | | × | | × | | × | | | | × | | | | |
| | | *Lippia stoechadifolia* | | | | | | | | | × | × | | | | |
| | | *Heliotropium indicum* | | | | | | | | | | | × | | | |
| Fern | OBL | *Thelypteris interrupta* | × | | | | | × | | | | | | | | |
| Twiner | FACW | *Ipomoea* sp. | | | | | | | | | | | | | × | × |
| Total | | | 6 | 4 | 3 | 4 | 4 | 3 | 3 | 2 | 2 | 3 | 3 | 3 | 4 | 3 |

The sites were statistically different ($p < 0.05$) for water content by weight, with the higher percentage values corresponding to the higher percentages of organic matter (sites 1, 5, 6 and 11). Lower percentage values of water content by weight were also found to correspond to higher percentage values of organic matter and vice versa (sites 2, 3, 4, 7, 8, 12 and 14). The remaining sites exhibited decreasing percentage in no discernible pattern (Figure 6). Application of the cluster analysis also revealed that the sites were statistically similar forming three groupings; group A, sites 10 and 12; group B, sites 3, 4, 7, 8, 9, 11, 13 and 14; and group C, sites 1, 2, 5 and 6 (Figure 7).

Soil porosity determined within the Black River Upper Morass on the 14 sites sampled revealed that 43% were clay, 21% loam, 14% sandy loam, 7% clay loam, 7% sandy clay loam and 7% silty clay (Figure 8). The soil constituent for each site is depicted in Figure 9.

## Hydrology

The dominant primary hydrological condition exhibited by all 14 sites was visual observations of inundation and/or saturation. Seven sites exhibited secondary hydrological condition of water-stained leaves. The areas within the Black River Upper Morass which remained inundated and/or saturated during the dry (August 2000) and wet (October 2000) seasons were lands in close proximity to the watercourses and the watercourses themselves, which were found to coincide with the wetland areas recorded for the locality. The dry areas were noted in ruinate lands, lands formerly used for agriculture and lands closer to the main road and rural communities (Figures 10 and 11).

Table 2. Morphological adaptations exhibited by dominants identified within the Black River Upper Morass

| Dominant species | Morphological adaptations | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Stem hypertrophy | Multiple stems | Aerenchyma tissue in stem | Hollow stem | Shallow root system | Soil-water roots | Floating leaves | Succulent leaves | Lignified root | Reduced root system |
| *Calyptronoma occidentalis* | | | | × | | | | | | |
| *Cladium jamaicense* | | | | × | | | | | | |
| *Dieffenbachia seguine* | | | | | | | | | | |
| *Eichhornia crassipes* | | | × | | | | × | × | | × |
| *Eupatorium odoratum* | | | | × | | | | | | |
| *Euphorbia* sp. | | | | × | | | | | | |
| *Haematoxylum campechianum* | × | × | | | | | | | | |
| *Heliotropium indicum* | | | | × | × | | | | × | |
| *Hydrocotyle umbellata* | | | | × | × | × | × | | | |
| *Lippia stoechadifolia* | | | | × | | × | | | | |
| *Lippia strigulosa* | | | | | | × | | | × | |
| *Malachra alceifolia* | | | | | | × | | | | |
| *Polygonum punctatum* | | | | | × | × | | | × | |
| *Psidium guajava* | | | | × | | | | | | |
| *Sagittaria lancifolia* | | | | × | | | | | | |
| *Solanum campechiense* | | | | | × | × | | | × | |
| *Thelypteris interrupta* | | | | × | | | | | | |
| *Typha domingensis* | | | | × | | | | | | |
| Total | 1 | 1 | 1 | 11 | 4 | 6 | 2 | 1 | 4 | 1 |

## DISCUSSION

Assessment of the Black River Upper Morass using the 3-parameter test as outlined by Tiner (1993) provided a methodology to determine whether or not the study site was still a wetland. The presence of vegetation, hydric soils and hydrological conditions makes the 3-parameter test applicable to the Upper Morass. However, a limiting factor to the methodology is that no one wetland can provide convincing evidence of all the indicators listed; for example, some wetlands remain 'dry' for significantly long periods of the year (Osmond *et al.*, 1995) and as such may not satisfy the criteria listed for the 3-parameter test. In addition, application of the 3-parameter test hinges on the definition of the term 'wetland'. The wetland definition used for the 3-parameter test was designed for regulatory purposes in the USA, thereby eliminating other types of wetlands defined under a broader definition for country purposes as well as that used by the Ramsar Convention, i.e. 'areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static, flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six metres'. For the purpose of this research, the Ramsar definition was used as a guideline and provided the limits of the Upper Morass wetland.

Of the 14 sites sampled during the wet and dry season, 71% contained plants typical of wetlands and 29% plants considered 'terrestrial' and atypical of wetlands. Twenty-one dominant plant species were identified, which exhibited a wetland indicator status of OBL, FACW or FAC. Osmond *et al.* (1995) stated that a community dominated by OBL or OBL and FACW should be a wetland provided the area's hydrology was not significantly altered by human disturbances and other impacts. The Upper Morass was drained via dykes, culverts and a pumping station from the 1960s–1980s for rice production after which it remained idle. The presence of plants morphologically adapted to life in inundated and/or saturated conditions and hydric soils provides evidence that the Upper Morass over time has reverted to wetland.

 

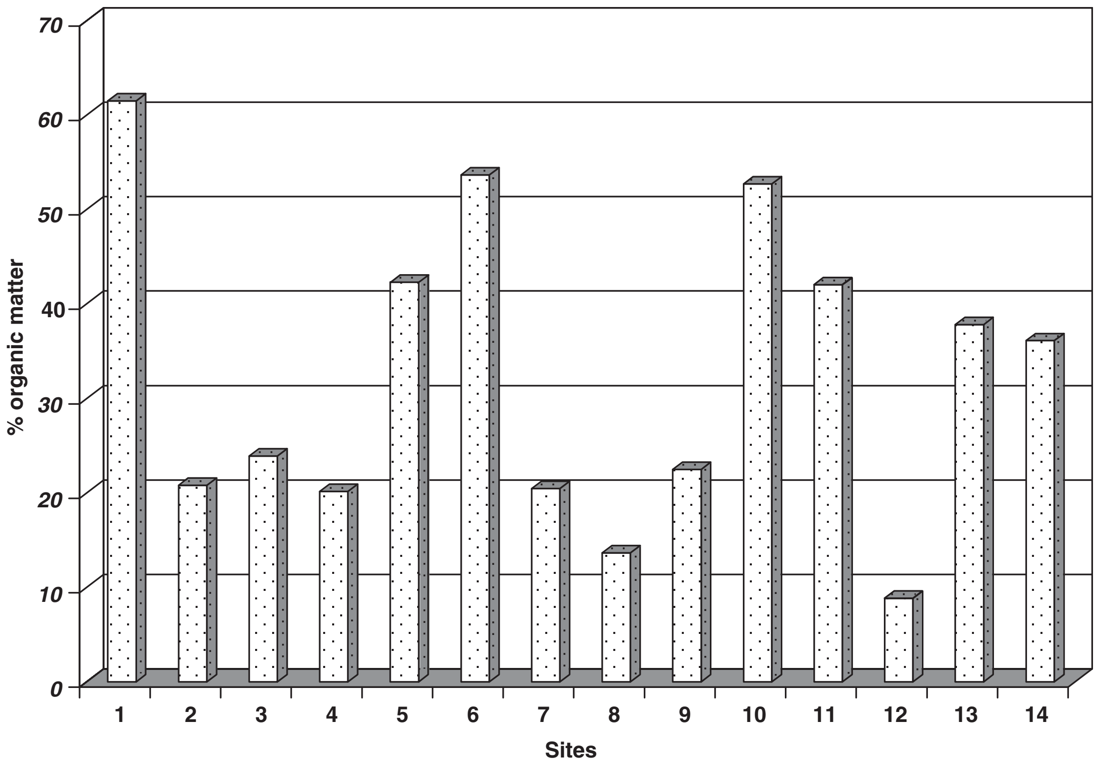


Figure 4. Organic matter of the soils sampled within the Black River Upper Morass.

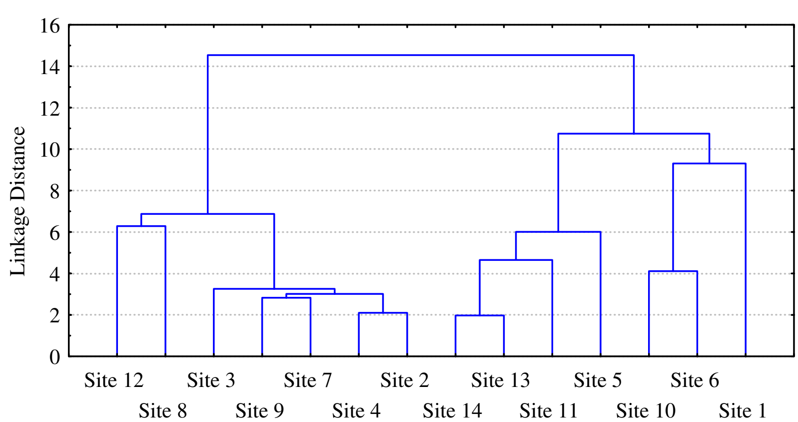


Figure 5. Cluster analysis diagram depicting relationships between sites for organic matter.

The predominant vegetation within the Upper Morass comprised herbaceous plants such as *Cladium jamaicense*, *Phragmites australis*, *Sagittaria lancifolia* and *Typha domingensis*; the aquatics *Eichhornia crassipes*, *Nymphaea ampla* and *Utricularia foliosa* and a few shrubs. The presence of these plants satisfies literature citations of species known for a marsh-type wetland (Finlayson and Moser, 1991; Mitsch and Gosselink, 1993). Osmond *et al.* (1995) considered that a marsh is dominated by floating-leaved plants and

 

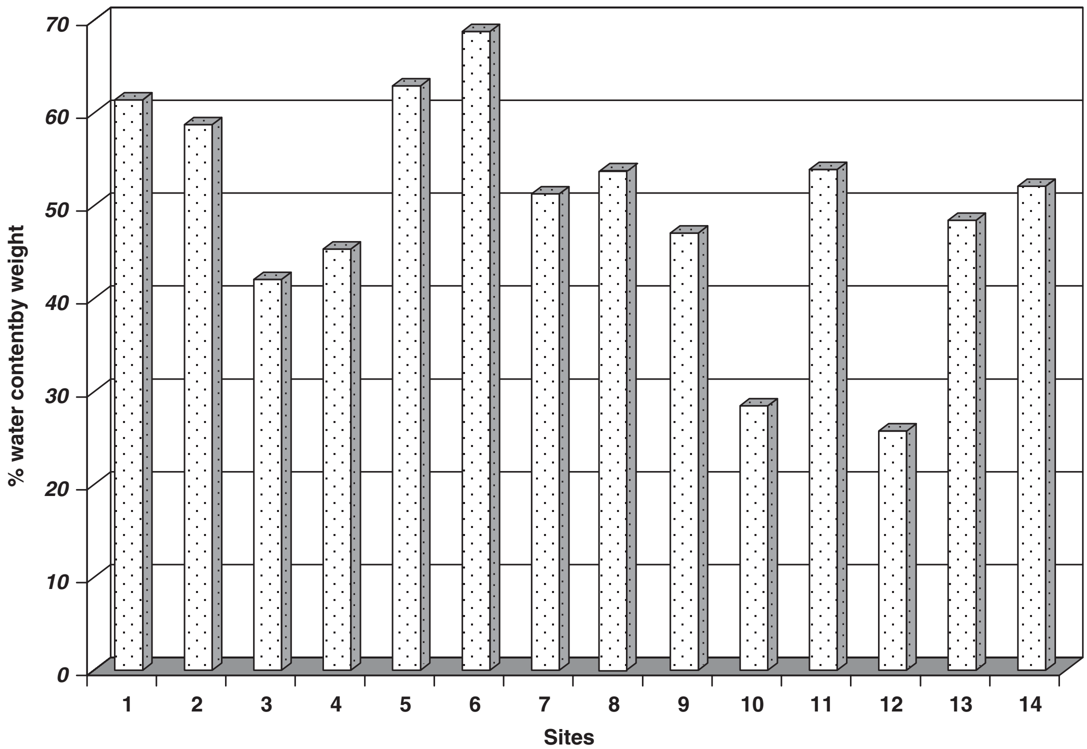


Figure 6. Water content by weight of soils sampled within the Black River Upper Morass.

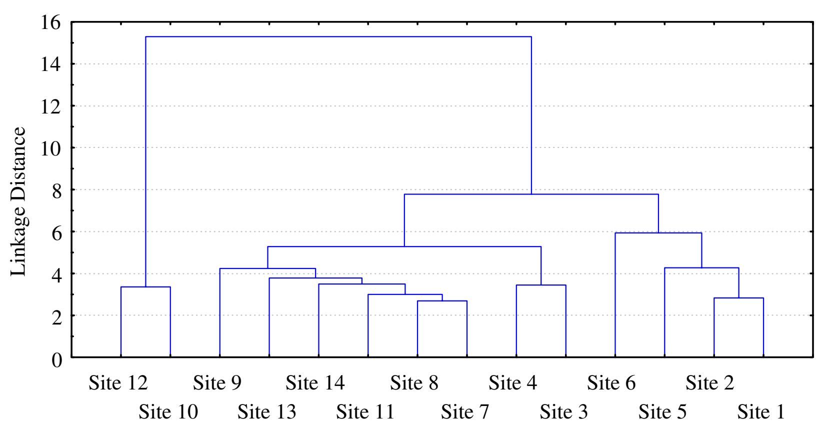


Figure 7. Cluster analysis diagram depicting relationships between sites for water content by weight.

emergent soft-stemmed aquatics and forms along slow-flowing streams and rivers. The Upper Morass exhibits all these characteristics. Use of the Cowardin *et al*. (1979) classification system allowed the Upper Morass to be categorized as a Palustrine Wetland with classes of Aquatic Bed and Persistent Emergent

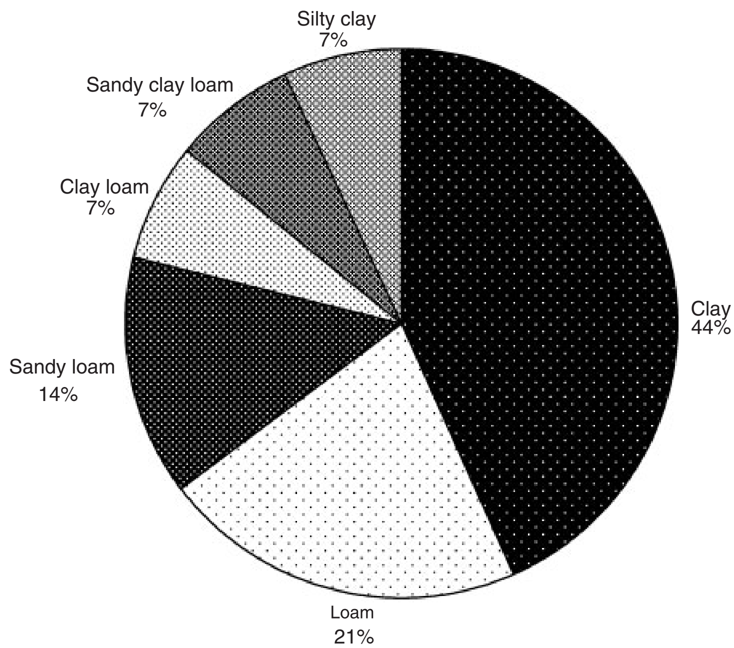


Figure 8. Pie chart showing percentage of soil types in the Black River Upper Morass.

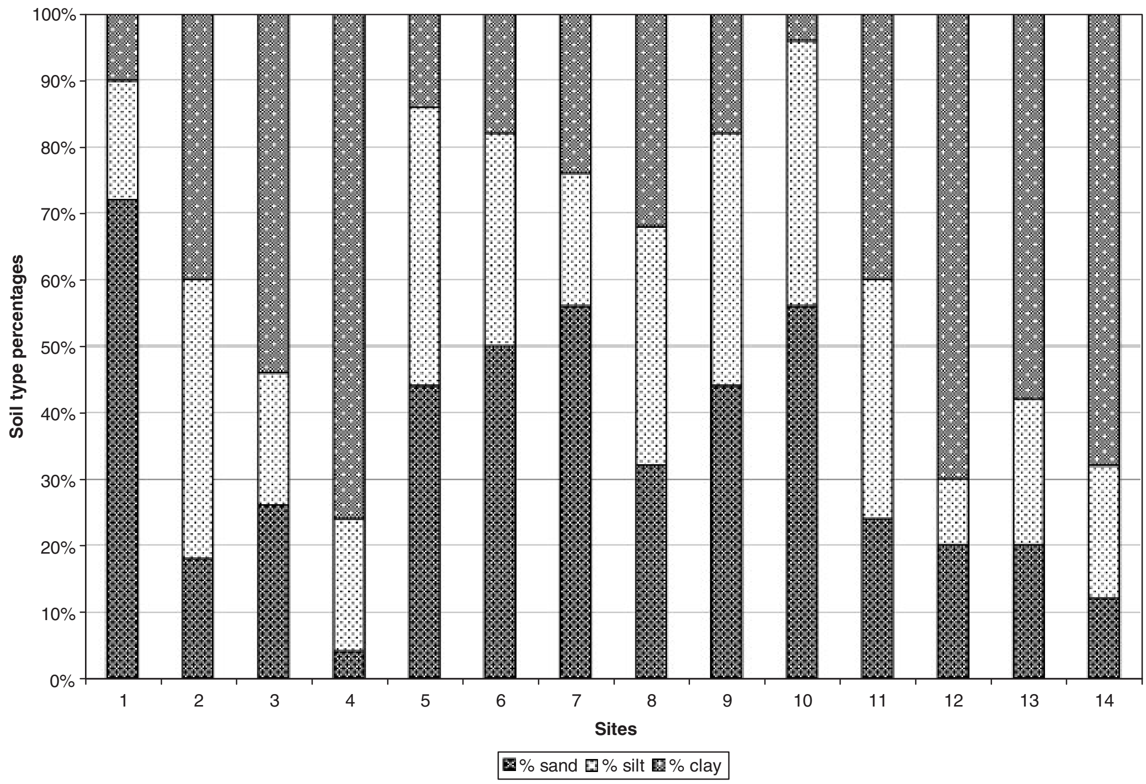


Figure 9. Basic soil constituents of each site sampled within the Black River Upper Morass.

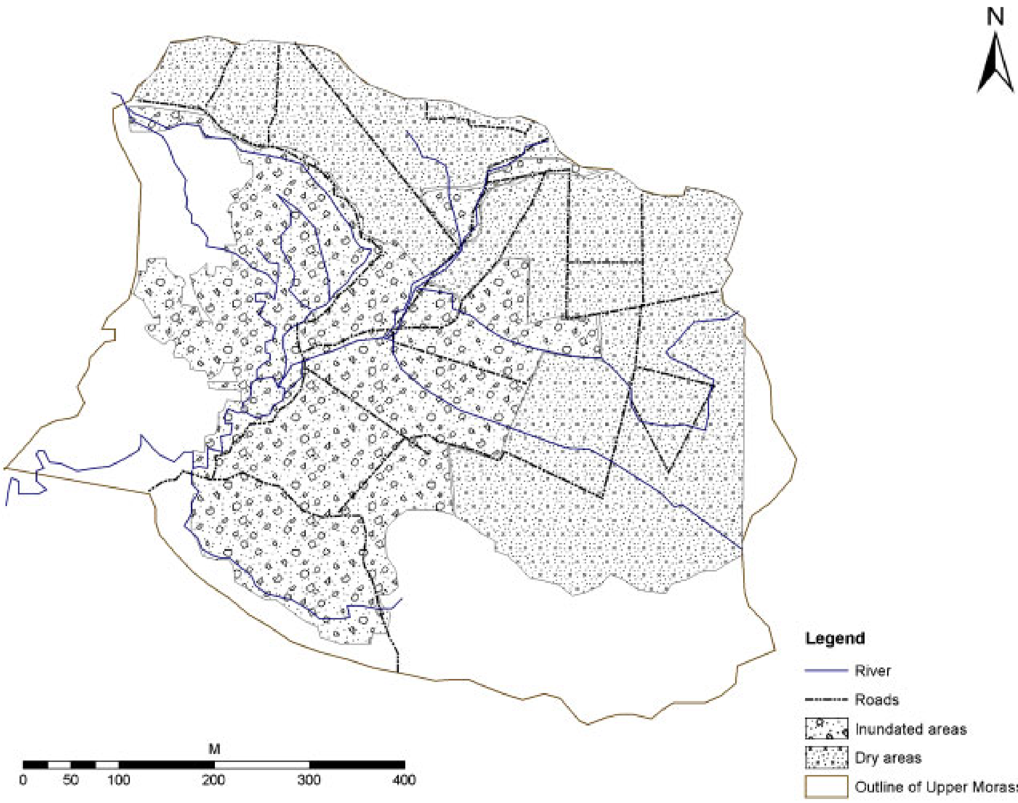


Figure 10. Hydrological conditions of the Black River Upper Morass in August 2000 (dry season).

Wetland and sub-classes of Floating vascular, Floating below water surface and Grass-like plants. The sub-headings are outlined below:

- System: Palustrine
- First Class: Aquatic Bed
  Constituent: Floating vascular (e.g. *Eichhornia crassipes*)
  Floating below water surface (e.g. *Utricularia foliosa*)
- Second Class: Persistent Emergent Wetland
  Constituent: Grass-like plants (e.g. *Typha domingensis*, *Cladium jamaicense*, *Phragmites australis*)

The hydrophytic vegetation observed in the Upper Morass also indicates the health of the ecosystem. Drainage of the Upper Morass in order to facilitate rice production has resulted in an ecosystem change in which aggressive invasive species have become established. This was evident by the presence of at least three known invasive species — *Melaleuca* sp., *E. crassipes* and *T. domingensis*. Wilcox (1995) reported that indicators of human disturbance included presence of invasive species; absence of sensitive species; presence of vegetation that is largely mono-specific or of one structural type; and the presence of very dense or sparse stands of vegetation.

The limitation to these indicators is that the presence of vegetation that is largely mono-specific or of one structural type may be used to describe another type of wetland — for example, herbaceous wetlands or tropical floodplains — and may not be supporting evidence of human disturbance. In addition, dense

 

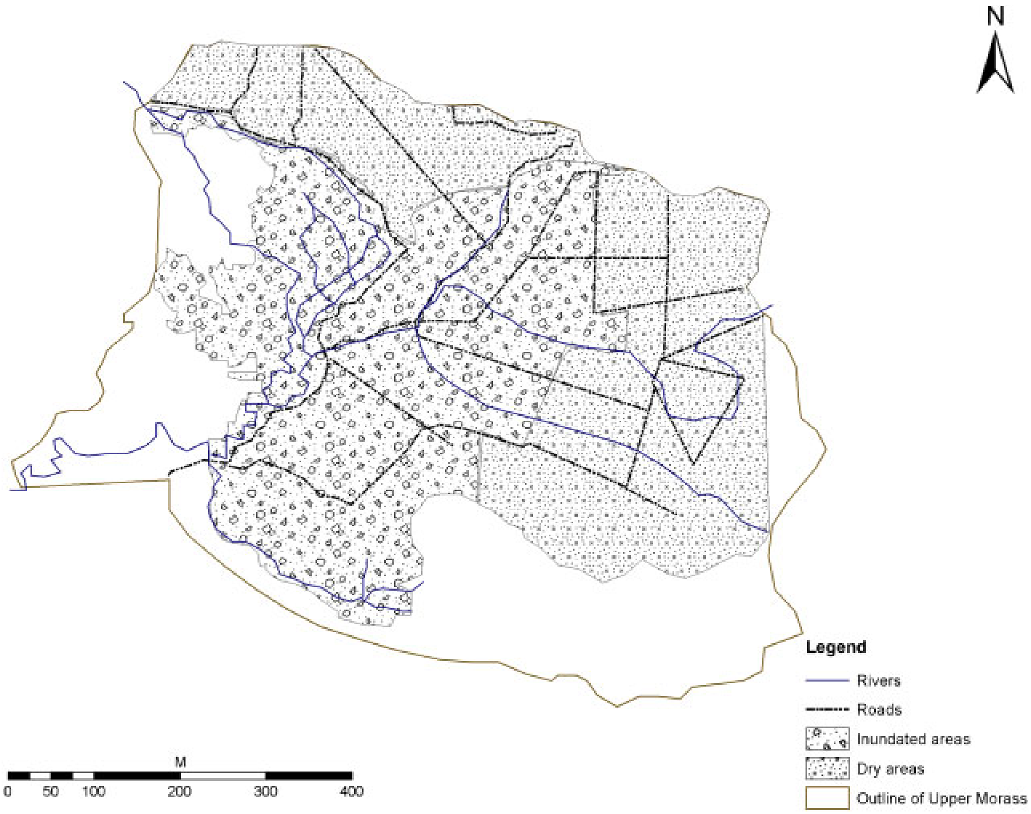


Figure 11. Hydrological conditions of the Black River Upper Morass in October 2000 (wet season).

stands of vegetation may be described as an upland wetland if terrestrial but morphologically adapted to periods of saturation and inundation. The presence of invasive species and the absence of sensitive species appear the likely indicators of human disturbance. Osmond *et al.* (1995) stated that as a result of disturbance, wetlands can be invaded by aggressive, highly tolerant, non-native vegetation such as *E. crassipes*, or can be dominated by a monoculture of cattails (*Typha* sp.) or common reeds (*Phragmites* sp.). *E. crassipes* was recorded at sites 4, 5 and 8 as well as in the Black River and its associated tributaries and *T. domingensis* was recorded at sites 5–8 and 12.

The soils sampled within the Upper Morass were predominantly mineral (non-sandy) and are not indicators of hydric soils. Tiner (1993), however, reported that soils can be classified as hydric if they are saturated or flooded long enough to produce anaerobic conditions that damage most plants but favour hydrophytes. As the plants observed are adapted for life in saturated or inundated areas, the primary indicator recorded for hydrological conditions was visual observations of inundation and/or saturation, and the odour of hydrogen sulfide was noted at the sample sites, the Upper Morass exhibits hydric soils.

The high values of organic matter were recorded in areas of extensive vegetation cover (sites 1, 5, 6, 10 and 11) and may also be attributed to the anaerobic environment within the Upper Morass, which facilitates reduced microbial breakdown. Gambrell and Patrick (1978) reported that anaerobic conditions reduced the rate of decomposition of organic matter in soil to half that under aerobic conditions. The remaining sites were open areas with sparse vegetation cover, thereby allowing greater heat penetration and faster microbial activity.

 

The values of water content by weight illustrated total soil saturation for the 14 sites sampled and supported the trend exhibited by organic matter. High organic matter values/high water content by weight values were correlated with extensive stands of vegetation (sites 1, 5, 6 and 11). In these areas, low light penetration, low microbial activity and water held by shallow and soil-water roots were contributing factors. High organic matter/low water content by weight was recorded for site 10, which was dominated by a stand of *Melaleuca*. *Melaleuca* sp. is known to change the hydrological conditions of the area in which it is located, resulting in the low value achieved. Low organic matter/high water content by weight was correlated with areas with limited vegetation. However, these plants exhibited adaptations of shallow and soil-water roots, which hold soil and the water within.

The groupings for water content by weight and organic matter derived from application of the cluster analysis (Figures 5 and 7) were found to coincide with the wetland areas identified in the photogrammetric analysis conducted prior to sampling as well as that recorded for hydrological conditions (Figures 10 and 11) and, consequently, indicated the areas within the Upper Morass which had reverted to wetland. In general, with the discontinuation of agricultural drainage activities, approximately 64% of the land, especially that in close proximity to the rivers, has reverted to wetland (indicated by Group B for both water content by weight and organic matter, which coincided with the areas covered by the Black River and its tributaries). The remaining 36% constitutes non-revertible land use, such as fish ponds and sugarcane plantations.

The predominance of clay, its variations and loam (Figures 8 and 9) are also directly related to the values of organic matter and water content by weight recorded (Figures 4 and 6). Tiner (1999) stated that the thickness of the capillary fringe is strongly correlated with soil texture and that fine-textured soils (e.g. clay) have small pores and can hold water under tension at higher levels than coarse-textured soils, and as such can form wetlands. The holding of water by fine-textured soils results in a poorly aerated environment, which was recorded throughout the Upper Morass.

The evidence of hydrological conditions within the Upper Morass was weak in terms of the criteria listed for wetland hydrology as only one secondary indicator was recorded. Two or more secondary indicators are required to satisfy the criteria. However, Tiner (pers. comm.) reported that the presence of observed saturation and/or inundation, although a primary indicator, is strong evidence of wetland hydrology. The presence of plants morphologically adapted to life in inundated and/or saturated hydrological conditions and hydric soils confirms that the Upper Morass exhibits wetland hydrology.

Hydrology in turn influences the types of soils present within the wetland as well as its function. The Upper Morass exhibits both temporary and total saturation and permanent saturation of the subsoil, i.e. it has both flood-water and groundwater soils (Blume and Schlichting, 1984). In addition, the water regime of a wetland can determine its hydrology. The Upper Morass is categorized as temporarily flooded ('a condition when surface water is present for brief periods, but the water table usually lies well below the soil surface') and saturated ('the substrate is saturated to the surface for extended periods, but surface water was seldom present') (Cowardin *et al*., 1979).

The presence of hydric, flood-water and groundwater soils as well as the hydrology (temporarily flooded and saturated) are strong indicators that the Upper Morass performs a settling basin function. Tollenaar (1982) reported that the topography of the area allowed the valley to act as a reservoir for water flow; drainage was not optimal, resulting in regular flooding and swampy conditions. However, the ability of the Upper Morass to perform this function may not be optimal based on its history. The United States Environmental Protection Agency (2001) reported that a degraded wetland loses its ability to control flooding. This was evident with the passing of Hurricane Ivan in 2004 in which the community of New River, located on the outskirts of the Upper Morass, was flooded by the waters from the Morass. As a result, some of the dykes within the Upper Morass have been broken to allow greater water flow through the gorge at Lacovia to the sea via the Lower Morass (pers. obs., May 2005). With the only outlet of the Upper Morass being at Lacovia, after which the water enters the Lower Morass, this settling basin function is especially significant to the Lower Morass (a designated Ramsar site), as the two systems are linked.

 

This is substantiated by the following case study. There are several known sources of nutrient release into the Upper Morass, including fertilizer runoff from sugarcane fields, fish-farm effluent at Bartons, and the production of dunder from the Appleton Distillery. Davis *et al*. (1998) reported that the level of inorganic nitrogen (nitrate + nitrite) was highest (90 μM) in the upper part of the Black River, where fertilizer runoff was the identifiable source. The nitrogen load within the Black River was found to decrease by 10% of the highest value ( ≈ 9 μM) by the time it got to the Lacovia Gorge, despite the additions from its tributaries (New River, 109 μM; Elim River, 110 μM). This indicates that the nutrients within the Black River are adsorbed or flocculate and settle out or are utilized before the water flows into the Lower Morass at Lacovia Gorge.

## Conservation

Wetlands in Jamaica serve the primary functions of critical feeding grounds and nurseries for a variety of fish, waterfowl and other wildlife; of critical habitat for plants; of shoreline protection and erosion control; of flood control/flow regulation; of groundwater recharge and discharge; of nutrient cycling; of sediment and toxicant removal; of windbreak and hurricane refuge. The Black River Morass is no exception. The Upper Morass at present provides a settling basin function, groundwater recharge and discharge (Tollenaar, 1982), nutrient cycling and a habitat for critical species of fauna, thereby providing justification for its need of conservation. Loss of this wetland represents loss of its functions and values to the adjacent communities in St. Elizabeth as well as to Jamaica as a whole.

Part of the conservation importance of the Upper Morass is as a habitat for the American crocodile, West Indian whistling duck and other wildlife. The American crocodile is listed on the IUCN Red List, is a CITES Appendix I species and is protected under the Wild Life Protection Act. The West Indian whistling duck is a globally threatened IUCN Red List species and CITES Appendix II species and is found only in the Greater Antilles and northern Lesser Antilles. The population is declining throughout its range; its status in Jamaica is not completely known and is threatened primarily by habitat loss (Haynes-Sutton and Hay, 2002). The Upper Morass has been reported as the best habitat for the West Indian whistling duck in Jamaica and possibly in the Caribbean (Massa and Haynes-Sutton, 1999).

Other birds such as *Nomonyx dominicus* (masked duck), *Anas discors* (blue winged teal), *Laterallus jamaicensis* (black rail), *Pardirallus maculates* (spotted rail), *Porzana flaviventer* (yellow breasted crake), together with herons, egrets, ibis, night heron, coots and grebes, as well as *Trachemys terrapen* (Jamaican slider), an endemic freshwater turtle species, are all known to occur in the Upper Morass (Massa and Haynes-Sutton, 1999; Haynes-Sutton and Hay, 2003). All birds in Jamaica are protected under the Wild Life Protection Act. In addition, Massa and Haynes-Sutton (1998) reported that the characteristics of the Upper Morass make it a likely habitat for the survival of *Diploglossus* (*Celestus*) *occiduus* (giant gallywasp), a nocturnal skink, considered rare and/or extinct in Jamaica and *Oryzomys antillarum* (Jamaican rice rat), also considered extinct. Two of the rarest freshwater fish species, *Cubanichthes pengellii* and *Limia melanogaster*, are confined to the upper reaches of the Black River (Massa and Haynes-Sutton, 1998).

The loss of nutrients as the Black River traverses between the Upper and Lower Morass and the function of the Morass identified by the three-parameter test implies a linkage between the two wetlands. In addition, there is documented research highlighting the effects on the Lower Morass by the Upper Morass (Björk, 1984; Government of Jamaica, 1985). These findings substantiate the need for conservation of the Black River Morass in its entirety, rather than as two discrete subsystems as at present. The integrity and continued international Ramsar designation of the Lower Morass may in fact be threatened by failure to conserve the Upper Morass.

The Upper Morass is a gazetted Game Reserve under the Wild Life Protection Act in which hunting of animals (including birds), removal of eggs or the nest of any bird and the use of any weapon to hunt any animal or bird within its boundaries is prohibited. The limiting factors to this Act are enforcement and the inadequate protection provided to the Upper Morass as a wetland and its functions. The Game Reserve status of the Upper Morass, however, should not be lifted as it serves as an instrument to protect the bird population present.

Other possible conservation measures for the protection of the Upper Morass include a Forest Reserve (Forest Act of Jamaica 1996), Protected Area (Natural Resources Conservation Authority Act of Jamaica 1991) and Wetland of International Importance (Ramsar Convention 1971).

Under the Forest Act of Jamaica, land may be declared a forest reserve or a forest management area if the use of the land can be controlled for the protection of national interest. The forest reserve and management areas may be used to conserve naturally existing forests, conservation of soil and water, recreation and protection of flora and fauna. In addition, under the Act, protected areas can be declared for lands required for flood and landslide protection, soil preservation, erosion, maintenance of water supply and protection of flora and fauna. Under the Forest Act, the Upper Morass can be conserved based on its fauna, flood protection capabilities and maintenance of water supply (groundwater recharge).

Under the Natural Resources Conservation Authority (NRCA) Act of Jamaica, land may be designated as a national park to be maintained for the benefit of the public; a protected area (land or water) which may preserve any object (animate or inanimate) or an unusual combination of elements of the natural environment that is of aesthetic, educational, historical or scientific interest, or a marine park, land lying under tidal water and adjacent to such land. The Upper Morass on its own could be declared a protected area under the NRCA Act based on the elements of educational and scientific interest. However, the declaration of the Black River Morass (Upper and Lower combined) as a protected area would satisfy elements of the natural environment, i.e. aesthetic, educational, historical and scientific, thus providing a greater impetus for conservation of both than as discrete subsystems.

Massa and Haynes-Sutton (1998) recommended a Managed Resource Protected Area (IUCN Types of Protected Areas) for the Black River Morass. A draft management plan was prepared for the proposed protected area; however, it was never implemented and is currently being reviewed. The type of protected area suited for the Black River Morass would have to be determined by the regulatory agency involved in such matters.

Under Section 33 of the NRCA Act, the Upper Morass can also be declared an Environmental Protection Area (EPA), which serves as a temporary measure to allow rectification of specific environmental impacts on an area — for the Upper Morass, to complete its reversion to wetland. Activities within a declared EPA may be prescribed by regulations in relation to the protection of the natural resources in the Upper Morass. The limitation to this declaration is the time frame to draft and implement regulations for the Upper Morass. The declaration of the EPA can be done prior to the declaration of the Black River Morass protected area, if chosen. In the interim, under the Permit and Licence System established under the NRCA Act, a permit is required for the modification and/or reclamation of wetlands, thereby providing a measure of conservation for the Upper Morass.

The Lower Morass by virtue of its biodiversity satisfies at least five criteria under the Ramsar Convention to be designated a Wetland of International Importance. However, a preliminary assessment of the Upper Morass using the Ramsar Information Sheet as a guide proved challenging as a result of lack of references pertaining to ecological studies (excluding avifauna) conducted within the area. Consequently, designation of the Upper Morass as a Ramsar Site (as recommended by Massa and Haynes-Sutton, 1999) thereby changing the boundaries of the present Ramsar Site, is premature without detailed ecological assessments of the Upper Morass.

Finally, with the number of legislative possibilities for conservation open to the Upper Morass, the regulatory agency in Jamaica would have to conduct a feasibility assessment on the proposed site in order to determine the areas in need of protection and ascertain which legislation, whether one or two, is best suited to protect and conserve the Upper Morass as a wetland and its functions. This assessment is recommended along with the detailed ecological study required for greater documentation and definitive conservation action.

 

## REFERENCES

Blume HP, Schlichting E. 1984. Morphology of wetland soils. In *Wetland Soils*: *Characterization*, *Classification and Utilization*. International Rice Research Institute. Proceedings of a workshop held March 26–April 5 under the joint sponsorship of IRRI, Soil Management Support Services, Agency for International Development and US Department of Agriculture. Bureau of Soils, Philippine Ministry of Agriculture.

Björk S. 1984. Summary optimum utilization study of the Negril and Black River Lower Morasses, Jamaica. Prepared for the Petroleum Corporation of Jamaica.

Cowardin L, Carter V, Golet F, LaRoe E. 1979. *Classification of Wetlands and Deepwater Habitats of the United States*. FWS/OBS-79/31. US Department of the Interior, Fish and Wildlife Service, Office of Biological Services: Washington, DC.

Davis M, Lalor GC, Rattray R. 1998. Nutrient status of the Black River System, St. Elizabeth, Jamaica. *Jamaican Journal of Science and Technology* **9**: 45–62.

Finlayson M, Moser M. 1991. *Wetlands*. IWRB, Slimbridge, UK, and Facts on File, Oxford, UK, and New York, USA.

Gambrell RP, Patrick WH. 1978. Chemical and microbiological properties of anaerobic soils and sediments. In *Plant Life in Anaerobic Environments*, Hook DD, Crawford RMM (ed.). Ann Arbor Science Publications: Ann Arbor, MI; 375–423.

Garrick LD. 1986. The Black River Lower Morass: a threatened wetland in Jamaica. *Oryx* **20**: 155–160.

Government of Jamaica (GOJ), Ministry of Agriculture. 1985. *The Agricultural Development Project on the Black River Lower Morass*, Vols 1 and 2. Japan International Co-operation Agency, Kingston, Jamaica.

Grontmij. 1964. *Black River Reclamation Project*. Government of Jamaica, Ministry of Agriculture and Lands: Kingston, Jamaica.

Harza Overseas Engineering Company (HOEC). 1976. Black River Upper Morass feasibility report. Submitted to the Government of Jamaica, Ministry of Agriculture. Appendix H — Environmental Assessment.

Haynes-Sutton AM. 1998. Surveys of West Indian whistling ducks in Black River, St. Elizabeth, Jamaica. Paper presented at Society for Caribbean Ornithology Annual Meeting, Guadeloupe.

Haynes-Sutton A, Hay DB. 2002. Surveys of migratory ducks in Jamaican wetlands — Phase one: January to April 2001. Report prepared for the Natural Resources Conservation Authority/National Environment and Planning Agency and Ducks Unlimited.

Haynes-Sutton A, Hay DB. 2003. Surveys of migratory ducks in Jamaican wetlands — Phase two: January to April 2003. Report prepared for the Natural Resources Conservation Authority/National Environment and Planning Agency and Ducks Unlimited.

Hudson B. 1983. Wetland reclamation in Jamaica. *Caribbean Geography* **1**: 75–87.

Massa AK, Haynes-Sutton A. 1998. Environmental Policy Framework, Parish of St. Elizabeth, Jamaica. Technical Support Services Inc. Prepared for the Natural Resources Conservation Authority Protected Areas Management Branch and the United States Agency for International Development.

Massa AK, Haynes-Sutton A. 1999. Black River Managed Resource Protected Area, St. Elizabeth, Jamaica — Management plan. Technical Support Services Inc. Prepared for the Natural Resources Conservation Authority Protected Areas Management Branch and the United States Agency for International Development.

Mitsch WJ, Gosselink JG. 1993. *Wetlands*. John Wiley: New York.

Osmond DL, Line DE, Gale JA, Gannon RW, Knoff CB, Bartenhagen KA, Turner MH, Coffey SW, Spooner J, Wells J, *et al*. 1995. *WATERSHEDSS*: *Water*, *Soil and Hydro-Environmental Decision Support System*. http://www.water.ncsu.edu/watershedss [Last date accessed October 25, 2005]

Proctor G. 1964. Vegetation of the Black River Morass. In *Black River Reclamation Project*, Grontmij (ed.). Appendix H, 9–10, Kingston, Jamaica.

Ramsar Sites Information Service. 2005. http://www.wetlands.org/RSDB/default.htm [Last date accessed October 25, 2005]

The World Conservation Union. 2004. *2004 IUCN Red List of Threatened Species*. http://www.redlist.org [Last date accessed October 25, 2005]

Tiner RW. 1993. Field recognition and delineation of wetlands. In *Wetlands — Guide to Science*, *Law and Technology*, Dennison MS, Berry JF (eds). Noyes Publications: New Jersey; 153–198.

Tiner RW. 1999. *Wetland Indicators — A Guide to Wetland Identification*, *Delineation*, *Classification and Mapping*. Lewis Publishers. CRC Press, Boca Raton, FL.

Tollenaar P. 1982. Water resources survey of the Upper Black River Basin, St. Elizabeth — Upper Morass and Essex Valley. Inventory of Groundwater Resources. Water Resources Division, Kingston, Jamaica; 7–8 and 16–17.

 

USDA (United States Department of Agriculture), NRCS (Natural Resources Conservation Service). 2001. *The PLANTS Database*. Version 3.1 (http://plants.usda.gov). National Plant Data Center, Baton Rouge, LA 70874-4490, USA. [Last date accessed October 25, 2005]

United States Environmental Protection Agency — Office of Water, Office of Wetlands, Oceans and Watersheds. 2001. *Threats to Wetlands*. EPA-843-F-01-002d. http://www.epa.gov/owow/wetlands/facts/threats.pdf [Last date accessed October 25, 2005]

UNEP-WCMC. 2005. *UNEP-WCMC Species Database*: *CITES-Listed Species*. http://www.cites.org/eng/resources/species.html [Last date accessed October 25, 2005]

Wilcox DA. 1995. Wetland and aquatic macrophytes as indicators of anthropogenic hydrologic disturbance. *Natural Areas Journal* **15**: 240–248.

 