FINAL

ENVIRONMENTALLY SENSITIVE AREAS STRATEGIC MANAGEMENT PLAN

REPUBLIC OF MAURITIUS

Prepared for:

MINISTRY OF THE ENVIRONMENT AND NDU
GOVERNMENT OF MAURITIUS

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ABBREVIATIONS

C&C	Command and Control
Cat	Category
DSB	Defined Settlement Boundary
EIA	Environmental Impact Assessment
ESA	Environmentally Sensitive Area
FS	Forestry Services
MoE	Ministry of Environment and NDU
MoHL	Ministry of Housing and Lands
MPU	Ministry of Public Works
NDS	National Development Strategy
NES	National Environmental Strategy
NGO	Non-Governmental Organisation
NPCS	National Parks and Conservation Service
NPDP	National Physical Development Plan
OPS	Outline Planning Schem(a)e
PES	Payment for Environmental Services
SGZ	Strategic Growth Zone
SL	State Land
UNESCO	United Nations Educational, Scientific and Cultural Organization
WHS	World Heritage Site
WRU	Water Resources Unit (a division of MPU)

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EXECUTIVE SUMMARY

This Strategic Management Plan forms one of several key documents aiming to provide a framework for identifying, classifying, legally mandating and managing Environmentally Sensitive Areas in Mauritius and Rodrigues. It forms part of a project commissioned by the Ministry of Environment & NDU, Government of Mauritius and carried out by NWFS Consultancy and associates over a 15 month period in 2008-09.

Environmentally Sensitive Areas (ESAs) are distinct landscape features or areas that are linked to the retention of environmental benefits of local, national and international importance. These benefits are delivered through both services delivered, such as effects on water quality and availability, and hazards avoided, such as risk borne from landslides or sea surge. They help strike a balance between the monetary value of pursuing growth through expansion of the built environment and the non-monetary value of retaining environmental functions that underpin long-term economic sustainability.

The main goal of ESA management is to implement activities and apply resources towards striking and maintaining this balance. This goal can be achieved by managing towards:

- sustainable economic development,
- protection of fragile habitats,
- ensuring a healthy supply of freshwater,
- conserving endemic flora and fauna,
- minimising lagoon degradation
- retaining landscape features contributing to scenic beauty and socio-cultural heritage
- maintenance of natural coastal defences, and
- maintenance of outdoor recreational and educational venues

This plan is structured to extend over a five-year period running parallel to the timeframe established for the District Council Outline Planning Schemes. It follows a four-step process that has been employed to link a three-tier system of categorising relative ESA value (see *ESA Classification Report*) to policy, legal and management instruments.

Three management categories form the core of the management framwork, viz.

1. Category 1 Management - Protection
2. Category 2 Management - Conservation & Mitigation
3. Category 3 Management - Sustainable Use

Management categories are consonant with the three-point system for assigning relative value, establishing ESA policy and establishing a legal mandate for future ESA identification and management.

A series of permitted activities are linked to ESA Type and Management category in line with the main management focus. A series of seven management measures are broadly prescribed to deliver effective action in ensuring protection and long-term integrity of ESAs. These include:

1. Buffers zones
2. Access
3. Amelioration and Improvement
4. Mitigation
5. Development Design
6. Information, and
7. Public Awareness

Not all measures are necessarily employed across all ESA Types and/or Management Categories.

The Ministry of Environment & NDU should act as the *de facto* secretariat for ESA management coordination given the current mixed model employed in Mauritius for managing natural resources and ensuing alignment of managerial responsibilities across a wide range of government agencies. Establishment of a secretariat is critical to the long-term success of any programme for management of ESAs. It is likely that additional personnel will be required for the Ministry of Environment to fulfill their necessary obligations under this arrangement.

It is expected that implementation could commence in 2010 and follow through a five-year timeframe. An implementation schedule outlines a basis for proceeding with facilitatory arrangements and subsequent deployment of management measures. Activities would, in the first instance, focus on those ESA Types and Features (sites) that have been identified for priority action through the vulnerability analysis (see *ESA Classification Report*). A new management plan will require drafting at the end of the five year term. More detailed site management plans may be required to advance activities at some ESAs, particularly those now inter-mixed with the built environment.

Monitoring of ESA integrity will play a central role in advancing towards the long-term management objectives. A detailed programme for monitoring ESA integrity focuses on individual ESA Types and methods to collect the time series data needed to detect degradation to the state condition of ESAs in Mauritius and Rodrigues.

Effective management of ESAs will only occur where a sound financial footing has been established. While government funding may play an active role in supporting ESA management, significant efforts to source support from non-governmental sources should be undertaken. Support could occur through grants, volunteering, sponsorship and other, innovative approaches to development of public-private partnerships towards retention of ESAs in the country.

1. BACKGROUND

1.1. What is an ESA?

An Environmentally Sensitive Area (ESA) is a common zonal designation that aims to identify and delimit specific landscape features that require more stringent assessment of allowable use.

Ecosystem Service Retention. An ESA designation is often afforded to specific areas that provide important ecosystem services of national importance. These services are delivered, often passively, through an ESA's geographic location, physical features, socio-cultural significance and/ or biological attributes. It is not uncommon to identify ESAs that deliver multiple services through a combination of site position and conditions.

Hazard Avoidance. Conversely, ESAs frequently identify areas where the hazard attached to general development is elevated or the risk to adjoining development is elevated through ESA modification. A change in ESA site conditions in this instance can lead to loss of invested capital and ecosystem services. Thus, an ESA may also identify *a zone where co-mingling of natural or heritage assets with certain land use investments will elevate the risk of devaluation to one or both classes.* This is not the same as defining a Natural Hazard Zone, such as attached to river flooding, tsunamis or earthquakes, that are specifically linking built up areas with a level of vulnerability to extreme natural events.

1.2. Role of ESAs in Land Use Planning

Environmentally Sensitive Areas (ESAs) as a land management concept in Mauritius and Rodrigues was first explicitly considered in the original 1994 version of the National Physical Development Plan (NPDP)(Ministry of Housing and Lands 1994) and later in the 1999 National Environmental Strategy (NES)(Government of Mauritius 1999). However, the notion of

maintaining the value of a national portfolio of environmental assets can, in a broad sense, be traced back to the landmark Environmental Protection Act (of 1991).

Subsequent updating of both the NES and NPDP (*National Development Strategy*, NDS 2003) have provided further clarification of the the intended role of ESAs within on-going land planning and development processes for Mauritius and Rodrigues. Significant change to the approach underlying the NDS took place over the intervening decade. The initial prescriptive approach to development planning was abandoned in favour of a more flexible organisational structure that emphasizes greater stakeholder involvement in determining how various development activities (in effect, zones) would fit with areas identified for strategic economic growth. The initial NDS called for a more rigid centralised prescription (zoning) of specific land use restrictions to targeted areas. Along with the contemporaneous updating of the main legislation governing land development processes in Mauritius, the Town and Country Planning Act 1954 and Local Government Act 1989, the revised NDS has established a more dynamic framework for land management over the next decade.

One of the significant change to this legislative framework, embodied by the 2004 Planning and Development Act and 2003 Local Government Act, is the increased planning responsibilities allocated to District Councils. Formulated policy and legal statutes indicate that responsibility should be substantively guided by Local Plans (*sensu* Ministry of Housing & Lands 2003), also referred to as Outline Planning Schemes (OPSs).

The preparation of OPSs for the various districts was finalised in 2006 (Ministry of Housing and Lands 2006). These consist of a series of documents outlining the socio-economic context, policies and proposals to be considered in guiding future land development. The spatial translation of the main policies and proposals were then articulated in a series of Development Strategy and Development Management maps for each district.

Policy and proposal development in the OPSs hinge on a sequential approach to assessing suitable sites for development. The sequential approach aims to consider development in relation to a series of ranked performance criteria cross-referenced to the spatial distribution of existing built-up area (Ministry of Housing & Lands 2003).

The presence of Environmentally Sensitive Areas is one of four core criteria put forward in the OPS to determine whether any development proposal is likely to be acceptable within the national legal and policy landscape, and to key locational preferences articulated in the OPS for each district. The significant role assigned to ESAs in land planning processes is underscored by the uniform application of ESA presence/absence as a critical factor in determining proposed development suitability, regardless of site location within, on the edge or outside Defined Settlement Boundaries (DSBs). Consequently, the weight of an ESA is considerable when determining the distribution and extent of land deemed suitable for future development.

1.3. Significance of ESAs as an Integrated Land Planning and Management Tool

Maintenance of ESAs in Mauritius & Rodrigues creates a practical basis on which to bridge local livelihoods, strategic national development and multi-lateral environmental agreements to which Mauritius is a signatory. Many of the identified ESA Types are fundamental to the long-term maintenance of local livelihoods, such intact mangroves and seagrass beds to fisheries and shellfish collecting, or healthy coral reefs to local boat and diving guides. Other types, such as boreholes (wells), rivers and streams, or reservoirs, are fundamental in determining the type and extent of economic activity on the islands through their role in supplying fresh water for drinking, agriculture and industry. Some types, such as coastal freshwater marshlands, or native forest remnants, link directly to the various international treaties and

conventions, such as the Ramsar Convention on Wetlands of International Importance (ratified in 2001) and the Convention on Biological Diversity (ratified in 1992) while simultaneously playing an important role in controlling soil loss and sediment export to the lagoon and mitigating flood potential.

These examples briefly illustrate how this pivotal role in bridging different demands is formed from the selection and classificatory approach adopted for ESAs (*ESA Classification Report*)(Ministry of Environment & NDU 2009a), the subsequent translation of these into concrete policy options and instruments contained in the *Policy Guidance for Environmentally Sensitive Areas* (Ministry of Environment & NDU 2009b) and the legal provisions needed to underpin policy and management of ESAs (draft ESA Bill 2009).

1.4. Three-tier ESA Categorisation: Integrating Assessment, Policy, Law and Management

The success of effort to manage ESAs and maintain the flow of ecosystem services they provide will rest in how well policy, legal and management structure coordinate with a view to:

1. avoiding any loss of ESA integrity through mis-matched or mis-placed development activities while,
2. minimising loss of opportunity for substantive, and sustainable, economic development.

Working towards these twin conditions must be placed in the context of Mauritius' geographic (but not socio-economic) isolation, small size, large and expanding reliance on coastal zone features, and transformation from a cash crop to more diversified economy.

With more than a third of Mauritius and most of Rodrigues occupied by ESAs, coordination requires a clear, consistent link between how ESAs are differentiated and how these differences should be approached in working

towards the main aim of ESA establishment, *viz*. to ensure that under-valued environmental features and functions continue to deliver the services in support of long-term sustainable development and enhanced quality of life for Mauritians. Differentiating ESAs should assist in identifying priorities and management measures appropriate to the level of potential loss attached to ESA degradation. It also introduces a measure of flexibility in decision-making.

A three-tiered ESA Category system was established to allow translation between ESA policy, legal and management instruments. This was distilled through a series of steps linking project objectives and best available environmental data with downstream decision-making structures.

Step 1. Establish Relative Value. ESA relative value (or quality) was established through a range of analyses/assessments distinguishing individual features or zones that were performing at different points along a ecosystem service spectrum. These were then collapsed into three categories denoting ESAs of High (Category 1), Moderate (Category 2) and Low (Category 3) value or quality. All ESAs, however, rank higher than areas not identifed as ESAs within the land use and development process from an ecosystem service perspective. Traditional land valuation approaches would establish alternate rankings.

Step 2. Integrate into Policy Approach. The relative value distinction drawn up for the various ESAs was translated into a three-point policy guiding positions that should be taken in relation to development activity in and adjacent to identified ESAs. Category 1 specifies that indefinite, full protection should be afforded an ESA of this rank with restorative activities engaged where needed to address prior degradation. All adverse impacts should be avoided. Category 2 indicates that the function of ESAs should be maintained, but that this could be achieved through restoration or mitigation actions attached to development. Policy guidance provided for Category 3 ESAs indicates that some sites could be transformed for other purposes, but

that (service) losses should be compensated. Release of Cat 3 ESAs should proceed within the context of maintaining a critical minimum area of any particular ESA Type. A range of incentives and regulatory instruments are employed to ensure that these positions are achieved.

Step 3. Define Legal Obligations, Rights and Responsibilities. Policy directives require that specific, enforceable provisions are made. Legislation or regulations define how ESA rankings should be interpreted within the context of the existing legal landscape. Draft legislation drawn up for ESAs in 2009 defines Category 1 ESAs as an area where all adverse impacts should be avoided. A Category 2 ESA should be free of all adverse impacts, unless authorised and in receipt of an EIA licence. Category 3 areas should be free of significant (rather than all) adverse impacts, subject to an EIA licence.

Step 4. Undertake Management Actions. With the relative value of the various ESAs within each type established, policy guidance provided and legal provisions mandated, the necessary pre-conditions for effective management towards a set of stated management goals and objectives attached to the 3-tiered rankings have been satisfied.

1.5. Purpose of the ESA Management Plan

This ESA Management Plan has been prepared in response to growing concerns over susceptible landscape features and the impacts attached to their loss or degradation. This plan was identified as a critical activity for completion within the 1999 National Environmental Strategy/National Environmental Action Plan, the 2003 National Development Strategy and the 2006 District Council Outline Planning Schemes. The purpose of this document is to provide a general structure for implementing management and a process to ensure that this is being undertaken in a cost-effective manner. It is primarily addressing ESA management at the Type level (see *ESA Classification Report*, MoE & NDU 2009), is strategic in scope and focussed at the national scale. The intent is to formulate management direction that

integrates, to the maximum feasible extent, any directives, policies and plans that have been formulated for areas now classified as ESAs. More specific site management plans are not covered in this document, but are referred to where available for specific ESAs or ESA Types.

2. MANAGEMENT GOALS AND OBJECTIVES

The ***Main Goal*** of ESA management is to implement activities and apply resources in a cost-effective manner towards long-term maintenance of ESA integrity and the sustained delivery of ecosystem services of national importance.

The ***Main Objectives*** in undertaking management of ESAs aim:

- To support sustainable development of the Mauritian economy
- To protect the most sensitive habitats containing the last remnants of the country's unique natural heritage
- To ensure the continued supply of clean freshwater
- To conserve flora and fauna endemic to Mauritius, Rodrigues and/or the Mascarenes
- To minimise degradation of lagoon function through collapse of habitat inter-relationships
- To retain landscape features contributing significantly to the scenic beauty and socio-cultural heritage of Mauritius
- To ensure that natural coastal defence features and processes are intact and functioning
- To maintain outdoor recreational and educational resources for Mauritians and visitors

A series of more specific objectives are attached to each of the three-tier ESA value categories in the *ESA Classification Report.*

3. PLANNING HORIZON

The horizon of this plan is intended to extend up to the year 2015. This will harmonise ESA management with the timeframe established for the District Council OPS (MoHL 2006). Synchronising the planning horizons of ESA management and Development Planning will increase the opportunities to minimise future discrepencies and maximise integration of lessons learned over the timeframe to reduce uncertainty and improve effectiveness. However, modifications to the plan can be made by the relevant implementing agency as is necessary to accommodate change in background conditions while ensuring that the main objectives continue as the focus of management effort.

4. DESIGNATION STATUS AND ESA TYPES

4.1. Designation Status

Designation status refers here to the current predominate use and tenure of an area. Use can be for residential/industrial, agricultural, forestry or conservation/recreation. Status equates to ownership, whether this is private or government-owned (State Land). If State Land, then status delimits the objectives and range of permissible use of an area as defined by law, policy and/or management. The main land designation categories considered in the classification and management of ESAs are listed in **Table 1** below.

The spatial distribution of the various categories is visually represented in the appended Land Designation Map (**Appendix 1**). It is important to note that the distribution of the main units are derived from existing geo-spatial coverages and that these may not necessarily reflect the precise limits of these areas due to rapid changes in land use and/or status since they were constructed. This uncertainty primarily effects the boundary geometry at the interface between Built Up Area, Agricultural Land and Unclassified Private/State Land.

Table 1. Principal land/marine designations considered in formulating management for ESAs.

Land Designation Categories
• Built Up Areas (Settlement Boundaries) • Pas Geometriques • Agricultural Land (Sugar and Tea) • State Forest Land • Conservation Area • Privately Owned Mountain Reserves • Unclassified Private/State Land • Unleased State Land (Offshore Islets only) • Leased State Land (Offshore Islets only)
Marine Designation Categories
• Marine Park • Fisheries Reserve • Unclassified Lagoon Area

4.2. ESA Types

Broad categories of environmentally sensitive areas that are related through a common set of recognisable features are referred to as ESA Types. The spatial distribution and status of fourteen of fifteen recognised ESA Types have been documented through a series of maps and profiles (*ESA Classification Report, Technical Report on Freshwater Wetlands*). The recognised ESA Types are listed in **Table 2** below.

The spatial distribution of ESA Types in Mauritius and Rodrigues are summarily presented in a map appended to this plan (ESA Type Map)(**Appendix 2a** and **2b**).

Table 2. Principal ESA Types that require management.

Terrestrial ESA Types
• Lakes & Reservoirs • Coastal Marshlands • Forests - High Native Content • Rivers & Streams • Upland Marsh • Caves • Steep Slopes • Boreholes (Wells) • Offshore Islets • Sand Beaches & Dunes
Marine/Littoral ESA Types
• Mangroves • Tidal Mudflats • Coral Reefs • Sea Grass Beds

5. MANAGEMENT CATEGORIES

Not all areas forming each ESA Type are of equal value. In the milieu of ESA function, some features will invariably deliver services valued higher than others. In some cases, this difference is based on prioritisation in the event of loss or decline. If there was a need in deciding what features to retain, which ones would be considered more essential? Alternatively, value could be considered as a quantity, with some areas simply containing more of any desirable feature than others. Still others might be considered more valuable by the uniqueness, rarity or irreplaceability of its features or functions. All of these considerations were integrated into a basis on which to distinguish relative value (see *ESA Classification Report*).

The three-point categorisation of ESAs has been translated into a policy framework for applying various instruments towards ESA protection. This

three-point system has also been integrated into draft legislation that would legally mandate certain actions, responsibilities and outcomes attached to a three-tier system of ESA categorisation. Management therefore needs to maintain consistency with this system.

The same three-tier system is translated into a series of Management Categories. These can be used as a framework for differentiating various levels of management action consistent with any particular area's status. They consist of the following:

Category 1 Management- Protection

Management of flora, fauna, soil, rock and water to ensure that the primary value of any ESA remains fully intact, that functions are not impeded whatsoever by activity within or adjacent to any area as defined by a buffer zone, and that appropriate amelioration is undertaken to improve functioning, where these actions will improve the long-term protection and/or value of the area.

Category 2 Management- Conservation & Mitigation

Management of flora, fauna, soil, rock and water to ensure that the primary value of any ESA is not substantively eroded, that functions are only temporarily or modestly impeded within or adjacent to any area as defined by a buffer zone, and that appropriate mitigation measures are undertaken to re-establish acceptable functioning.

Category 3 Management- Sustainable Use

Management of flora, fauna, soil, rock and water to ensure that any changes consequent to land use maintain function within established acceptable minimums and that design and form of permitted development adapts to and

integrates, to the maximum feasible extent, features necessary for continued ESA function.

6. PERMITTED ACTIVITIES

The range of allowable uses, or permitted activities, depends on the ESA Type and the categorisation of any particular area within each type. A matrix of permitted activities has been devised to assist in identifying how ESA type and category combine to identify activities compatible with the objectives established for these. The lowest impact activities prescribed for an area should take precedence, whether attached to designation status of land or ESA management category. In some cases, conditions on allowable use should be tailored within more-detailed site management plans. The matrix of permitted activities for the various ESA Types and Categories are outlined in **Table 3** below.

The schedule of permitted activities is subject only to circumstances where significant analysis indicates that infrastructure of national strategic importance must be situated in ESAs (or their buffer zones) due to conditions of cost and logistical necessity. In these circumstances, the underlying necessity should be well-documented to establish the primacy of a 'no alternative' scenario.

Table 3. Permitted activities according to ESA Type and Category (1,2, or 3).

	Education & Research	Tourism & Recreation	Fishing & Aquaculture	Livestock grazing & Ranching	Agriculture	Residential/Commercial Construction	Mining & Quarrying
Lakes & Reservoirs	2,3	2,3	2,3				
Coastal Marshlands	1,2,3		2,3	2,3	3	3	
Forests - High Native Content	1,2,3	2,3		3			
Rivers & Streams	1,2,3	1,2,3	1,2,3				
Upland Marsh	1,2,3			3	3	3	
Caves	1,2,3	2,3				3	
Steep Slopes	1,2			2,3		3	3
Boreholes (Wells)						3	
Offshore Islets	1,2	2,3	3	3	3	3	
Sand Beaches & Dunes		2,3				3	
Mangroves	1,2	1,2	2,3				
Tidal Mudflats	1,2	2,3	3	3		3	
Coral Reefs	1,2,3	2,3	3				
Sea Grass Beds	2,3	2,3	2,3				

7. MANAGEMENT MEASURES

A range of measures are needed to ensure that the future status of ESAs meets with the desired condition attached to their assigned Management Category. Measures targeted here aim to differentiate between ESA types across Management Categories to maintain consistency with the three-tier

system and range of permitted activities attached to each of these (**Table 3**). Measures consist of seven broad elements:

1. Buffer Zones
2. Access
3. Amelioration & Improvement
4. Mitigation
5. Development Design
6. Information
7. Public Awareness

An effective programme of monitoring requires more specific attention since this will ultimately establish if the integrity of a site is being maintained. A proposed ESA monitoring programme is described in considerably greater detail in Section 11 of this plan.

7.1. Buffer zones

The application of a spatial buffer to a core area is commonplace in national and international resource policy, planning and management. For example, the UNESCO Biosphere Reserve concept is principally structured on the identification of a Core Reserve Area with a surrounding Buffer Zone. The distinction in this case has to do with the range of permitted activities. But other buffer zones simply act to expand the allowable use schedule attached to a core area as a form of 'spatial insurance', in recognition that the knowledge necessary to manage in the face of uncertainty is almost always imperfect.

Buffer zones have been proposed or established for a number of ESA Types through existing management and policy and these are adopted here. The bulk of ESA types, however, have to date not been recognised formally and thus require buffer zone assignment. Effort has been made to identify a buffer zone that can be effective in limiting ESA degradation in

those categories (usually Categories 1 and 2) where adverse impacts are to be strictly curtailed or only acceptable under strict compliance with prescribed mitigation. A schedule of proposed buffer zones as they relate to individual ESA types and the three-tier system of Management Categories are listed in **Table 4**.

Table 4. Proposed buffer zones (in metres) according to ESA Type and Management Category (1,2, or 3).

ESA Type	Category		
	1	**2**	**3**
Lakes & Reservoirs***	30	30	NA
Coastal Marshlands*	30	30	30
Forests - High Native Content	50	50	0
Rivers & Streams**	33[A], but >16/8/3[B]		
Upland Marsh*	30	30	30
Caves	20	20	20
Steep Slopes	20	10	10
Boreholes (Wells)***	200	200	0
Offshore Islets	30	30	0
Sand Beaches & Dunes****	30	30	0
Mangroves	10	10	NA
Tidal Mudflats	45	45	NA
Coral Reefs	40	40	20
Sea Grass Beds	50	50	25

* Outline Planning Schemes & Draft Wetlands Bill 2009

** (A) subject to exceptions described in Section 26(1) Rivers and Canals Act

** (B) minimum for Rivers /Rivulets/Feeders, Forests & Reserves Act, 4th Schedule

*** Outline Planning Schemes - Water Resources Unit/MPU

**** set-back high water mark, Study on Coastal Erosion (Baird Report)

NA - not applicable, no ESAs assigned category 3 status

Buffer zones proposed here that are not attached to previous recommendations, policies or legal acts, represent 10% of the square-root mean area of *n* polygon features constituting an ESA type and then rounded up to the nearest 5 metre interval. This simple approach aims to provide some scaling of buffer-to-feature area while maintaining a simple system that is practical to manage. More sophisticated scaling methods

could be employed, but buffers would vary within ESA types and across areas, complicating management and enforcement. During this inaugural plan, the priority is to establish an effective system of ESA buffering that is easy to implement at minimal cost.

7.2. Access

The integrity of ESAs will to a large extent depend on the level of access. Areas with minimum restrictions placed on conditions of access will continue to receive the bulk of impacts attached to an inadequate national system of solid waste management, over-use of fragile features, and unmanaged exploitation of soil, rock and biological resources. Provisions for restricting access should be undertaken to ensure the most vulnerable features are isolated from further degradation. ESAs falling within designated lands such as National Park, Nature Reserves, State Forest Lands and Le Morne WHS that strongly control access are adopted here. ESAs found outside these areas require further attention, but only Priority (Most Vulnerable) Areas are identified for attention under the horizon of this plan. Coastal Freshwater Marshlands and Caves (with adjoining pits) in Category 1 and 2 are the main ESAs requiring measures curtailing access. Measures could include fencing, signposting, or other means of primarily preventing or curtailing vehicular, livestock and squatter access to these areas. Where practical, access should be restricted at the distance of the included buffer zone. In residential or other areas commonly inhabited or visited, access restrictions should be designed to improve or conform to the aesthetic quality of surroundings.

7.3. Amelioration & Improvement

Some ESAs currently require measures to improve their state due to the cumulative impacts of past and on-going pressures and threats that have left them in a relatively degraded condition. The main measures required to ameliorate and improve the condition of ESAs are described in Table 5.

A number of these have already been employed to positive effect and form part of management proposed for various ESAs under complementary initiatives, such as a series of management plans developed for Offshore Islets, Conservation Management Areas and privately-owned or long-leased initiatives, such as the Ferney Valley or Francois Leguat Reserve (Rodrigues).

The principal amelioration activity regards the removal of solid waste from Category 1 and 2 Coastal Marshland, Offshore Islet and Cave ESAs and various efforts to restore native and endemic flora and fauna to Forest with High Native Content, Offshore Islets and Coastal and Upland Marsh. For many ESAs within these types, there are on-going programmes aimed at improving conditions and new initiatives are not required.

7.4. Mitigation

Many Category 2 and 3 ESAs are open to a wider range of permitted activities, but mitigation should be carried out during these activities to ensure that ESA functions are not permanently impaired or, where needed and feasible, that these functions are transferred to an appropriate alternate location.

In some instances, mitigation may constitute the primary means of compensation for impacts as outlined in the *Policy Guidance for Environmentally Sensitive Areas* (MoE & NDU 2008b) and draft ESA legislation (pending). These measures should also be deployed in circumstances where infrastructure is installed due to national strategic importance in ESAs otherwise off-limits to sited development.

Table 5. Ameliorative actions according to ESA Type and Category (1,2, or 3).

ESA Type	Category		
	1	2	3
Lakes & Reservoirs	NA	NA	NA
Coastal Marshlands	waste removal, weeding	waste removal	NA
Forests - High Native Content	weeding	weeding	weeding, enrichment
Rivers & Streams	waste removal	NA	NA
Upland Marsh	weeding	weeding	NA
Caves	waste removal	waste removal	NA
Steep Slopes	enrichment	NA	NA
Boreholes (Wells)	NA	NA	NA
Offshore Islets	waste removal, weeding, enrichment, translocation, eradication	waste removal	NA
Sand Beaches & Dunes	filao removal, enrichment, hard structure removal	filao removal, enrichment	NA
Mangroves	NA	enrichment	NA
Tidal Mudflats	waste removal	waste removal	NA
Coral Reefs	eradication	eradication	NA
Sea Grass Beds	NA	NA	NA

weeding,eradication refers to removal of alien invasive species only

enrichment, translocation refers to endemic and/or native flora and fauna appropriate to habitat

7.5. Development design

Category 3 ESAs focus on management in the presence of the widest range of potential uses, including construction of residential or commercial infrastructure. In these instances, the promotion of any such development would be subject to design criteria. The purpose of these design criteria is to ensure that a balance is struck between the form and function of any infrastructure and that characterising the ESA. The aim in doing so is to maintain a minimum acceptable level of functioning and retention of key ESA features while acknowledging a need to be flexible in balancing present and future economic concerns. The Planning and Policy Guidance attached to the District Council Outline Planning Schemes are adopted here as the core basis for designing development in and adjacent to ESAs. More site-specific design criteria should form site management plans for ESAs in need of greater attention due to proximity to Built Up Areas or heightened use by the general public or tourists. These specific criteria should delimit acceptable intensity and appearance parameters of any permitted activity.

7.6. Information

A wide range of information on ESAs has been generated. Monitoring and research will continue to bring new information to bear on future management of ESAs. There is a critical need to ensure the integrity of this information, that it remains up-to-date and that a mechanism for sharing data on ESAs between various government ministries and agencies is constructed and activated. In the absence of a national geo-spatial data centre, a network capable of maintaining geo-spatial data standards and flow between contributing members should be actively pursued.

Assessment of changes to all ESAs on an annual basis is not cost-effective since many features will only change at this scale through

alterations resulting from a direct and drastic change in land use. These should primarily effect Category 3 ESAs. Consequently, information on these changes, if any, should be rolled up in the operational GIS on a case-by-case basis and a new map published annually including these updates. The process of obtaining an *ESA Clearance* and/or *Environmental Impact Licence* should trigger planning at the relevent ministry/agency to undertake a post-development survey of the ESA. A full account of the state and distribution of all ESAs on Mauritius and Rodrigues should be made at the end of the management plan horizon in 2015.

7.7. Public Awareness

Establishing a factual understanding of ESAs within the national public mindset is fundamental in avoiding mis-understanding of what they are, where they are located, and the purpose behind their establishment. The long term integrity of ESAs will depend to a great extent on public opinion and understanding that these areas aim to protect and conserve resources critical to their future and that of their children. Investing in public awareness should improve cooperation, open up opportunities to engage a wider range of policy instruments and reduce costs attached to amelioration and maintenance in the face of reduced degradation. ESAs delimit resources and natural heritage features that are of significant value to Mauritians and Rodriguens and efforts need to be undertaken to inform them of this new land management programme. Proposed measures to be undertaken during the life of this plan include:

- a nationwide (school) competition to identify a standard symbol/emblem to identify ESAs on site-based signage, maps and other materials.
- an atlas of Environmentally Sensitive Areas that could be made available for use in schools and environmental education programmes

- detailed interpretative signs at frequently visited flagship ESAs that explain the purpose of this designation
- well-crafted marketing campaign aiming to heighten awareness through printed and electronic media.
- Organise ESA amelioration campaigns that publicise and incentivize participation by volunteers and non-governmental organisations.

8. MANAGEMENT MECHANISMS

Implementation of prescribed measures should take place along a practical path that finds the best balance between constraints invariably imposed by capacity, budget and stakeholder interests. Use of mechanisms that can yield the desired outcome in Category 2 and 3 ESAs while maximising stakeholder involvement and minimising government-sourced costs will allow public resources to be applied in priority to ensure the long-term integrity of Category 1 ESAs, particularly those under greatest pressure (within Critical Risk Zone, see map, **Appendix 3**. A number of policy instruments have been described that offer opportunities to manage ESAs across the three-tier system. Current land tenure status (state land – uncommitted, leased, committed and private ownership) forms the nexus that defines the most desirable mechanisms to employ across ESA types and categories. These are outlined in **Table 6**.

Table 6. Main mechanisms and institutional arrangements for management according to ESA Type and Land designation status. (C&C – Command and Control, PES – payment for environmental services, WRU – Water Resources Unit, NPCS – National Parks and Conservation Service, FS – Forestry Services, FISH – Fisheries Division, MoHL – Ministry of Housing & Lands).

ESA Type	State Land			Privately held	
	Committed	**Leased**	**Uncommitted**	**Large-holding (> 5 ha)**	**Small-holding (< 5 ha)**
Lakes & Reservoirs	C&C (WRU/MPW)	NA	NA	self-management	self-management
Coastal Marshlands	C&C (NPCS)	C&C (NPCS)	C&C (NPCS)	self-management, conservation easement, PES	cooperative agreement, conservation easement, land swap then NPCS
Forests - High Native Content	C&C (NPCS, FS)	lessee agreement with FS and monitor	C&C (NPCS, FS)	NPCS, FS under cooperative agreement	conservation easement, land swap then NPCS
Rivers & Streams	C&C (NPCS,WRU)	C&C (NPCS,WRU)	C&C (NPCS,WRU)	C&C (NPCS,WRU)	C&C (NPCS,WRU)
Upland Marsh	C&C (NPCS, FS)	NA	NA	NA	NA
Caves	C&C (NPCS) outsource option	lessee agreement with NPCS	C&C (NPCS) outsource option	cooperative agreement, NPCS	cooperative agreement, conservation easement, land swap then NPCS
Steep Slopes	C&C (WRU/MPW)	lessee under agreement	C&C (MoHL)	under terms	under terms
Boreholes (Wells)	C&C (WRU/MPW)	C&C (WRU/MPW)	C&C (WRU/MPW)	C&C (WRU/MPW)	C&C (WRU/MPW)
Offshore Islets	C&C (NPCS) outsource option	C&C (NPCS) lessee agreement and monitor	C&C (NPCS) outsource option	NA	NA
Sand Beaches & Dunes	C&C(BA)	lessee under agreement & MOE monitor	C&C (MOE monitor)	self-management under provisions	self-management under provisions
Mangroves	C&C (FISH)	lessee under agreement	C&C (FISH)	C&C (FISH)	C&C (FISH)
Tidal Mudflats	C&C (NPCS/FISH)	C&C (FISH)	C&C (FISH)	NA	NA
Coral Reefs	C&C (FISH)	C&C (FISH)*	C&C (FISH)	NA	NA
Sea Grass Beds	C&C (FISH)	C&C (FISH)	C&C (FISH)	NA	NA

* in event of aquaculture lease

9. INSTITUTIONAL ARRANGEMENTS

The networks of identified ESAs are distributed across a wide range of existing land units administered and managed by a wide variety of ministries, public agencies and private owners. Two main themes define the type of institutional arrangements currently in existence for management of natural resources and environment in Mauritius and Rodrigues

Site-based management *arrangements occur where all resources contained within any given area are intended to be managed by a single entity*. This, for example, takes place on Offshore Islets (depending on designation) or in private agricultural lands. Alternatively, some forms of management focus on one or more closely linked environmental components, such as water, air, forests, or fisheries. Arrangements for ***resource-based management*** *prescribe management authority over any particular resource across a wide range of land units*. A broad mixture of these two arrangements can lead to significant overlap and gaps in defining the lead responsibility for implementing effective management and protection of natural resources, particularly when these combine to form the core mission of a single authority.

Current arrangements in Mauritius follow this mixed model. Ideally, direct management responsibility would be harmonised towards either site-based or resource-based arrangements, at least within each authority. The case of the National Parks and Conservation Service serves as a good example, whereby a mixed model is built into the fundamental mission of the entity. Responsible for site-based management of the National Parks, the service mission also specifies. Ideally these responsibilities should be separated into two entities: one responsible for the site-based management of National Parks (combined with other conservation units) and another resource-based and focused on the conservation and management of biological resources.

Institutional arrangements for the management of ESAs reflect some modifications to this end and extend to employ some policy instruments that

could lead to more cost-effective management on privately-held lands (see MoE 2009b). However, they have generally remain concordant with existing responsibilities (**Table 6**) since harmonisation ultimately will need to occur through a much broader process capable of undertaking significant institutional re-alignment and re-capitalisation.

In the interim, *the Ministry of Environment & NDU should act as the de facto secretariat for ESA management coordination.* Without a specific coordinating body, it is unlikely that implementation will proceed with a view to harmonise across ESA Networks in Mauritius and Rodrigues. However, the practical need for ESA management is best met through (slightly modified) institutional arrangements over the timeframe specified for this plan.

10. TIMEFRAME FOR IMPLEMENTATION

A schedule outlining a practical schedule for implementation of management measures within the planning horizon is appended to this document (**Appendix 4**). The subset of ESAs identified through the vulnerability analysis (see ESA Classification Report) are given priority. These reside almost entirely within the identified, 500 metre ESA Critical Risk Zone that emanates from existing Built-Up Areas in Mauritius (see map, **Appendix 3**).

11. MONITORING PROGRAMME

A detailed, stand-alone monitoring programme for the various ESA types can be found in **Appendix 5**.

12. FINANCIAL MECHANISMS FOR FUNDING MANAGEMENT

Implementation is strongly, but not solely, shaped by the resources available to carry out activities. Reasonably well paid, trained and dedicated personnel with access to reliable equipment constitute a sine quo none of successful management. Achieving these conditions requires a financial commitment on behalf of those entities stewarded with maintaining the integrity of ESAs, but

ultimately those that stand to benefit from the continued services that these areas provide should contribute to their long-term management.

A wide range of prospective mechanisms could be employed to underpin the financial sustainability of ESA management. A number of these are already engaged to support activities. The main proposals for financially supporting management of ESAs are summarised in **Table 7**. Specific details linked to the successful activation of these mechanisms are the remit of more in-depth financial planning and site management plans and are not given here.

It is important to note that the proposed mechanisms aim to connect directly to the user-pays principle. For ESAs where a direct-use value is not easily assigned, an endowment approach, such as the national Conservation Fund, or making use of research and conservation interests, both nationally and internationally, should be structured to ensure long-term support for management.

Table 7. Main financial mechanisms proposed to underwrite cost of measures attached to ESA management.

ESA Type	Main Financial Mechanisms
Lakes & Reservoirs	water rates
Coastal Marshlands	building permit fees, land sales tax
Forests - High Native Content	conservation fund, deer ranching fees, NGO endowment
Rivers & Streams	water rates, drawing rights exchange (water banking), conservation fund
Upland Marsh	conservation fund
Caves	conservation fund, waste removal services charge
Steep Slopes	afforestation grants, NGOs, conservation fund, sponsorship
Boreholes (Wells)	water rates
Offshore Islets	conservation fund, lease fees, visitors fees
Sand Beaches & Dunes	tourist landing fee, campement fee
Mangroves	coastal defence fund, property tax on coastal zone properties (pending cadastre)
Tidal Mudflats	conservation fund
Coral Reefs	fishing license, diving fees, coastal defence fund, sponsorship, grants
Sea Grass Beds	fishing license, diving fees, boat registration fees

13. REFERENCES

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Ministry of Housing & Lands. 2003. *National Development Strategy*. *Vols 1 and 2*. MoHL, Port Louis.

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14. APPENDICES

APPENDIX 1. Land Use Designation Map

APPENDIX 2. ESA Type Map

APPENDIX 3. ESA Critical Risk Zone Map

APPENDIX 4. Implementation Schedule

APPENDIX 5. ESA Monitoring Programme

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APPENDIX 1. LAND USE DESIGNATION MAP

APPENDIX 2. ESA TYPE MAP

APPENDIX 3. ESA CRITICAL RISK ZONE MAP

APPENDIX 4. IMPLEMENTATION SCHEDULE

APPENDIX 4. GENERALISED IMPLEMENTATION SCHEDULE

YEAR 1 AND 2

ACTIVITY	CATEGORY			YEAR 1				YEAR 2			
	1	2	3	1	2	3	4	1	2	3	4
INITIATION											
Financial planning for ESA mgt											
Agree inter-agency collaboration											
Establish ESA secretariat at MoE											
Agree inter-agency reporting											
Agree inter-agency data-sharing											
Mobilise financing for Priority Areas											
Initiate public awareness campaign											
Select management mechanisms											
AGREEMENTS											
Negotiate management with private owners											
Agree inter-agency support for measures on SL											
MEASURES											
Public Awareness - contract for Atlas prep											
Restrict Access - signage Marshlands											
Restrict Access - barriers Caves											
Amelioration - waste removal Caves											
Amelioration - waste removal Marshlands											
Restrict Access - 30m setback parking Beaches											
Amelioration - reduce filao in set-back											
Amelioration - enrich plant Scaevola, other natives											
Public Awareness - organise Coastal Cleanup											
MONITORING											
Agree inter-agency monitoring coordination											
Establish ESA monitoring baseline											
Arrange for annual ESA monitoring report											
Commence new monitoring											
STATE OF ESAS REPORT											
Inaugural Report											
Annual Reporting											
ESA MAP & PLAN UPDATING											
Compile changes to ESA condition through EIA											
Report changes and amend map											
National ESA audit and prepare new map											
Commence preparations for new ESA mgt plan											

IMPLEMENTATION SCHEDULE (Continued)

YEAR 3 AND 4

ACTIVITY	CATEGORY			YEAR 3				YEAR 4			
	1	2	3	1	2	3	4	1	2	3	4
INITIATION											
Financial planning for ESA mgt											
Agree inter-agency collaboration											
Establish ESA secretariat at MoE											
Agree inter-agency reporting											
Agree inter-agency data-sharing											
Mobilise financing for Priority Areas											
Initiate public awareness campaign											
Select management mechanisms											
AGREEMENTS											
Negotiate management with private owners											
Agree inter-agency support for measures on SL											
MEASURES											
Public Awareness - contract for Atlas prep											
Restrict Access - signage Marshlands											
Restrict Access - barriers Caves											
Amelioration - waste removal Caves											
Amelioration - waste removal Marshlands											
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Amelioration - enrich plant Scaevola, other s											
Public Awareness - organise Coastal Cleanup											
MONITORING											
Agree inter-agency monitoring coordination											
Establish ESA monitoring baseline											
Arrange for annual ESA monitoring report											
Commence new monitoring											
STATE OF ESAS REPORT											
Inaugural Report											
Annual Reporting											
ESA MAP & PLAN UPDATING											
Compile changes to ESA condition through EIA											
Report changes and amend map											
National ESA audit and prepare new map											
Commence preparations for new ESA mgt plan											

IMPLEMENTATION SCHEDULE (Continued)

YEAR 5

ACTIVITY	CATEGORY			YEAR 5			
	1	2	3	1	2	3	4
INITIATION							
Financial planning for ESA mgt							
Agree inter-agency collaboration							
Establish ESA secretariat at MoE							
Agree inter-agency reporting							
Agree inter-agency data-sharing							
Mobilise financing for Priority Areas							
Initiate public awareness campaign							
Select management mechanisms							
AGREEMENTS							
Negotiate management with private owners							
Agree inter-agency support for measures on SL							
MEASURES							
Public Awareness - contract for Atlas prep							
Restrict Access - signage Marshlands							
Restrict Access - barriers Caves							
Amelioration - waste removal Caves							
Amelioration - waste removal Marshlands							
Restrict Access - 30m setback parking Beaches							
Amelioration - reduce filao in set-back							
Amelioration - enrich plant Scaevola, others							
Public Awareness - organise Coastal Cleanup							
MONITORING							
Agree inter-agency monitoring coordination							
Establish ESA monitoring baseline							
Arrange for annual ESA monitoring report							
Commence new monitoring							
STATE OF ESAS REPORT							
Inaugural Report							
Annual Reporting							
ESA MAP & PLAN UPDATING							
Compile changes to ESA condition through EIA							
Report changes and amend map							
National ESA audit and prepare new map							
Commence preparations for new ESA mgt plan							

APPENDIX 4. Additional Notes on Implementation

These additional notes provide additional detail in relation to the Activiteis described in the main table. They are sequentially referenced by number.

A. INITIATION

(1) The implementation of management activities is contingent upon securing the necessary funds to pay for personnel, transport, materials and other costs. The implementation of activities may prove more cost-effective through out-sourcing to private-sector consultants, but a financial plan will need to be prepared. The financial plan would identify targeted sources of funding, project cash flow requirements, and itemise implementation costs within a cost centre framework.

(2) MoE will act to coordinate inter-agency collaboration. Agreements would solidify commitment and establish roles, responsibilities and reporting as they are linked to management activities.

(3) This would require the full-time commitment of at least two personnel. It is recommended that provision of the necessary personnel arrive as a new ministerial budget item, rather than further allocation from existing ministry staff time.

(4) The ESA Secretariat should coordinate reporting from participating agencies and to funding agencies, including Cabinet.

(5) Existing agreements for inter-agency data sharing may be sufficient, but it is recommended that the following prospective agencies/ministerial divisions spearhead efforts, viz.

   a. Geospatial data : Cartography Division, Ministry of Housing and Lands, act as the main coordinating body to ensure accuracy and integration
   b. Physico-chemical monitoring data: ICZM and Environmental Monitoring Divisions of MoE to share main coordinating responsibilities.
   c. Biodiversity data: National Parks and Conservation Service should act as the main national repository of data on natural, endemic and alien invasive taxa.

(6) Efforts to acquire financing should parallel ESAs identified for priority action. This is an on-going process that will require collaboration with private and NGO sectors to meet the needed monetary support for implementation. Sponsorship schemes, international grants, volunteering and other in-kind contributions should, ideally, form part of the financial base for future management. Third-party arrangements, such as those initatied with MWF for Ile aux Aigrettes/Round Island, often prove the most cost-effective approach in coordinating these various activities towards management objectives.

(7) A campaign to raise awareness should be structured and initiated during year 1 in order to ease subsequent activities and garner maximum support. Focus of campaign should be on purpose and value of ESAs and their role

in supporting long-term economic sustainability. This has already commenced through a series of articles in the national press, workshops and meetings resulting from the ESA project.

(8) A schedule of possible management mechanisms has been provided, but a short-list of the most cost-effective should be drawn up for Priority areas in the first instance.

B. AGREEMENTS

(1) These would establish the basis on which the future state condition of ESAs on privately-owned lands could be maintained. An emphasis on Category 1 ESAs would necessarily take priority since these sites/features would place the greatest restrictions on any future change in land-use.

C. MEASURES

Details of management measures are given in Section 7 of the plan

D. MONITORING

(1) WRU, Fisheries Division, Forestry Services, NPCS, MoE – Environmental Monitoring Division should coordinate their respective monitoring activities in order to ensure maximum coverage of ESAs. Category 1 ESAs stand in priority to Category 2/3 areas where limits on available resources constrain monitoring efforts. ESAs within Critical Risk Zone should also be given priority, except where longer-term changes threaten integrity of ESAs, e.g. lagoon warming on coral survival

(2) A monitoring baseline will need to be established thgrough a well-planned monitoring campaign. A set of long-term monitoring parameters would then be enumerated in a sample of undamaged sites drawn from across the three categories. Ideally, sites would be chosen in a random manner within each category (a stratified random sampling approach)

E. STATE OF ESAs REPORT

(1) The inaugural report would be used to institutionalise the objectives and rationale behind ESA management. It would also contain baseline reference for monitoring

(2) Annual reporting of the 'State of ESAs' provides an opportunity to update activities and maintain an official record of ESA management and activities of the ESA Secretariat.

F. ESA MAP & PLAN UPDATING

(1) Changes to ESA condition and distribution would be determined from monitoring data and record of ESA Clearances

(2) ESA Map should be amended by updating status of ESA features in the Geographic Information System

(3) The semi-decadal audit would entail more deliberate and systematic field visitation of discrete ESAs (e.g. marshlands, caves, tidal flats, mangroves, etc) to verify their distribution and state condition.

(4) A new 5-year plan should be rolled out no later than the first quarter of year 6, but preferably by end of 4th quarter year 5. This should be drafted in close concert with map audit

APPENDIX 5. ESA MONITORING PROGRAMME

MONITORING PROGRAMME FOR ENVIRONMENTALLY SENSITIVE AREAS

Prepared for:

MINISTRY OF THE ENVIRONMENT AND NDU

GOVERNMENT OF MAURITIUS

Prepared by:

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Table of Contents

INTRODUCTION

What is environmental monitoring?

Environmental monitoring is the repeated observation of a biological system in order to detect change. Monitoring programs in ESA's are designed to detect negative changes in the environment and are an integral part of environmental management decision-making. Ideally, monitoring programs are designed to identify the cause of an environmental change, assess the acceptable range of change for a particular system and to measure the levels of impacts. Measuring a large number of parameters or a large number of sites is frequently prohibitively expensive, and therefore monitoring is best if kept specific. Monitoring programs can also assess management actions to determine if they are cost-effective and are achieving their aims.

Local communities and schools are frequently encouraged to become engaged in monitoring programs. When community groups are aware of what is happening in the environment and they understand why, they may be able to assist in the protection and maintenance of sites.

Designing a successful monitoring program needs to follow five basic steps:

1. ***Why are we monitoring?***

   Identify the purpose of the monitoring program. Keep it simple and achievable with the resources available.

2. ***What are we monitoring?***

   The biological and physical parameters selected need to be logistically possible to collect. The aim is to design a sampling program that requires minimum monitoring effort yet still produces adequate data that is statistically and scientifically meaningful. Management agencies need to know the level of dynamism and the

extent of natural change in a system, so that the impacts they are interested in monitoring can be separated from the normal dynamics of the system.

3. Where are we monitoring?

Where the sites are established will depend upon what is being monitored but it is important to choose sites that are representative of the type of system that is being monitored. Sites should be monitored at the same time of the year. True random sampling is the most reliable method of sampling a population but it is not necessarily practical or cost-effective. Sampling is often stratified to account for natural variation in the community, where random sampling is not possible. Ideally if monitoring is aimed to detect a human-induced change in the environment, then the monitoring program will commence before the change is going to occur. Termed a Before-After-Control-Impact, BACI designed monitoring programs are considered the most reliable method of detecting an environmental impact (Stewart-Oaten et al, 1986, Basset et al 2001). The BACI design samples two localities prior to an impact occurring at one of the locations, then resamples both localities after the impact, and assumes any change that occur between the localities is due to the impact.

4. Data management and analysis

Data are expensive to collect and need to be managed appropriately. Field data collection sheets can ensure that data is collected in a standard manner, reducing confusion and ensuring nothing is forgotten. Data must be uploaded as soon as possible after collection, it is always best if the collector uploads the data as they can check the data for accuracy as they upload and can also add other observations. Hard and soft copy backups should always be stored. Data needs to be analyzed and feedback reports provided to management agencies. It can be difficult to interpret small changes

in systems without long-term data. However, if a system has dramatically changed in area or composition it can warrant a recommendation of more sampling in the area to discover the extent and cause of the change.

5. Review of monitoring programs

We recommend a 5-year review of all monitoring programs. The following questions need to be addressed at that time:

a. Have the monitoring programs been undertaken in a consistent manner?
b. Have the programs identified effects and did these results influence management behaviours?
c. Have new or different threats been identified in the ESA's, can they be addressed appropriately in the monitoring program or does a different study need to be undertaken?

Defining the critical effect size or the limit of unacceptable change

Environmental monitoring is based on the assumption that if anthropogenic impacts become unacceptable, management actions will be taken to prevent further impacts or to remediate the affected system. Defining the critical effect size is a two step process: first, environmental monitoring is undertaken to detect an impact; second, management decides at what point does an impact become unacceptable and warrant management action.

Environmental threats may change

The monitoring programs outlined below have been designed to address current threatening processes to these environments. Environmental threats, however, are frequently diverse and dynamic, and may change spatially and temporally. Hence management decisions based on monitoring programs need to weigh up the benefits of long-term data collection versus the flexibility to address new environmental risks when they occur.

SEAGRASS BEDS

Main pressure

Nutrient enrichment of coastal waters via land- or water-based activities is the most significant cause of seagrass decline worldwide. The major component that leads to nutrient loading and eutrophication is nitrogen. Direct measurement of overenrichment is difficult because estuarine conditions dilute and dissipate nutrient loading through tidal and current action. Characteristics of eutrophication include: seagrass loss, algal growth, anoxia and fish kills. These are all indicators of late eutrophication and ecosystem breakdown.

Monitoring targets: Seagrass Community Health & Water quality

1) Seagrass Community Health

Regional maps of seagrass habitat are the most important initial information for assessing the extent of seagrass meadows and for designing management and monitoring programs. When local-scale impacts such as nutrient loading are the main concern then fine-scale monitoring is necessary. Seagrasses are dynamic seasonally and interannually; therefore these natural patterns of temporal change need to be quantified so as to distinguish them from anthropogenic influences. Sampling needs to be stratified along the disturbance gradient keeping other important environmental gradients such as water depth, temperature, salinity, and available light standardized. The intertidal monitoring program described below follows the standardized seagrass monitoring protocols outlined in Global Seagrass Research Methods (Short & Coles 2001) and Seagrass

Watch – Manual for Mapping and Monitoring Seagrass Resources by Community Volunteers (McKenzie, Campbell & Roder, 2001).

Intertidal Monitoring Program

Fixed transect sites are recommended for intertidal seagrass monitoring but this technique can also be used for subtidal seagrass meadows using SCUBA. Sites are to be measured biannually at the same time in wet and dry season. At each site, three parallel transects of 50 m in length are to be established 25 m apart running perpendicular to the shore (Plate 1). The advantage of this technique is spatial analysis and within site variability can be calculated if necessary.

Plate 1: Setting of monitoring transects perpendicular to the coast line.

The monitoring program requires paired study areas that include a possible polluted site (close to a major stream or township) and a control site that is adjacent to natural habitat or low density residential (avoid intensive agricultural areas which may have high levels of fertilizer).

The paired sites should be relatively homogeneous in topography, substrate and wave action. Seagrass should be the dominant habitat in both sites.

Establishing the permanent transects

Necessary materials & equipment

- GPS
- Compass
- Labelled plastic fencing posts, or long tent pegs
- Mallet
- Subsurface buoy & rope
- Plastic labels
- Cable ties

When suitable sites have been found, transect sites will need to be permanently marked. In order to reduce the amount of equipment left in the field and to reduce the attention it might attract only the central transect will be permanently marked.

⇒ Knock a plastic star picket into the ground leaving 10 cm above the substrate surface.

⇒ Attach a Sub-surface buoy to the picket with on a steel trace (10 cm)

⇒ Attach a plastic site label that states the government department undertaking the monitoring. The site tag is marked with a code signifying the location, the site number and the transect number. The transect number on the permanent star picket will always be "2", because only the middle transect is being marked.

⇒ Record the coordinates of the transect point using the GPS (Global Positioning System).

⇒ Using a compass determine the bearing of the coastline and then determine the perpendicular bearing out to sea (add/or subtract

90 degrees to the coastal direction). Record the bearing on the data sheet.

⇒ Attach a 50 m measuring tape to the star picket and gaze at a fixed point out to sea on the bearing and walk until the end of the tape. Be sure to always walk on the left side of the tape, as measurements will be taken on the right.

⇒ At the end of the transect check the original marker is along the bearing.

⇒ Knock in another star picket leaving 10 cm above substrate level

⇒ Attach a second site marker tag to the top of the picket with cable ties.

⇒ Establish transects 1 and 3. They will lie 25 metres to the left and right, respectively of the origin of transect 2 (Plate 2).

⇒ Sample for species, percentage cover and state of seagrass at fixed intervals along each transect.

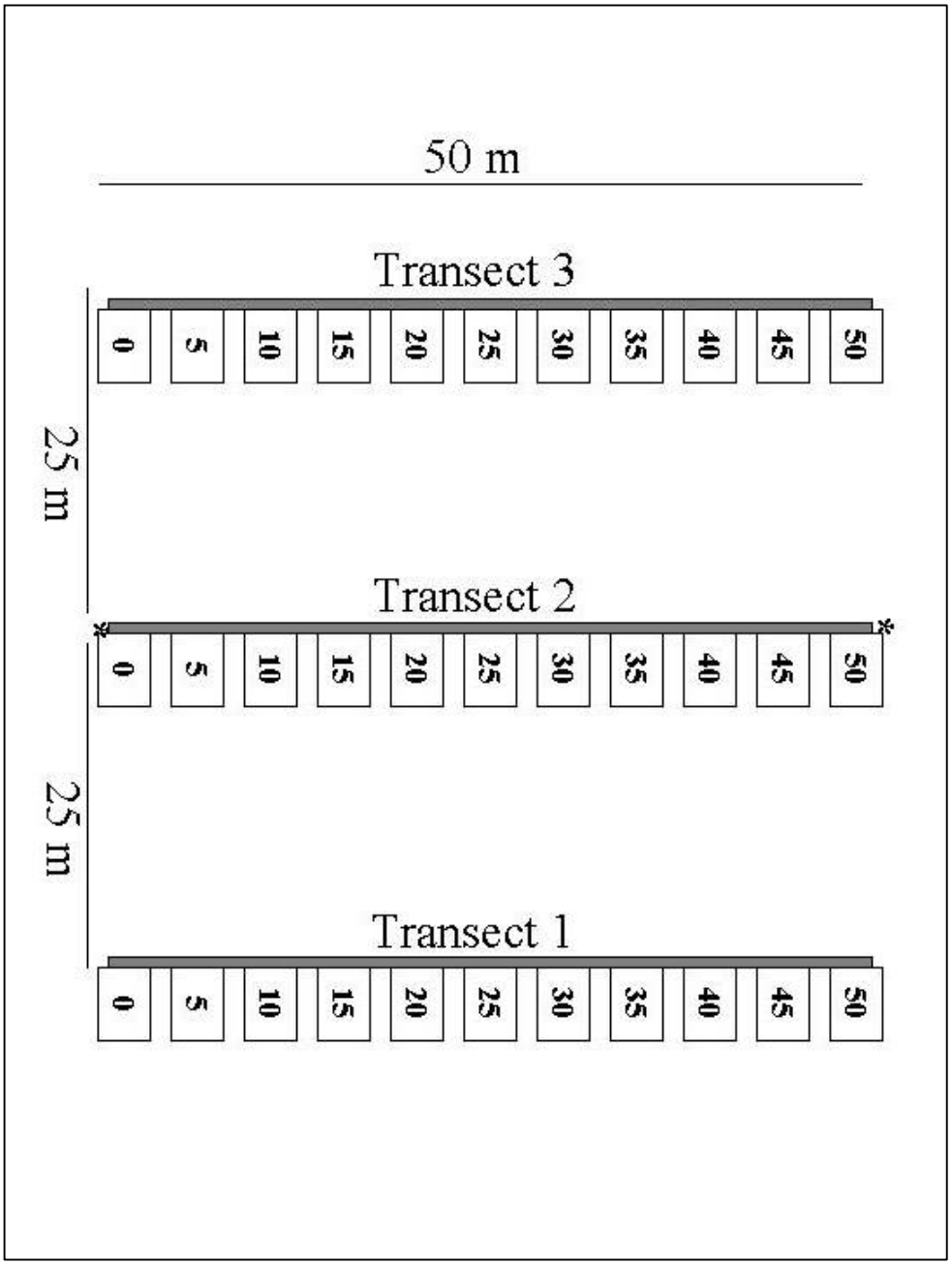


Plate 2: Seagrass monitoring transects layout

Seagrass Monitoring

Necessary materials & equipment

- GPS
- Digital camera – (Digital cameras provide easily accessed photos and avoid the risks of losing film, however they do not cope well with saltwater)
- Compass
- 6 x 50 cm plastic or aluminum tent pegs
- Mallet
- 3 x 50 m fiberglass measuring tape
- 50 x 50 cm quadrat frame of metal or hard plastic
- Plastic bags (eg ziplock type) and waterproof labels
- Magnifying glass
- Clipboard
- Datasheets
- Quadrat photo labeler
- Seagrass cover guide to estimate percentage cover
- Seagrass photo guide

Transect monitoring

⇒ Locate central marker and lay 50 m tape between star pickets in Transect 2.

⇒ Establish transects 1 and 3 as explained earlier.

⇒ Mark the start and end of transects using plastic pegs and lay 50 m tape between pegs ensuring that the bearing is identical to Transect 2.

⇒ Lay and secure all three 50 m tapes with plastic pegs to begin.

⇒ Record start time, at 5 m distances along the transect, starting at 0 m lay a standardized quadrat (50 x 50 cm) and record seagrass parameters.

⇒ Record end time for the transect and move to other transects.

⇒ Once the seagrass parameters are complete, remove and carefully store all field equipment.

Seagrass Parameters

Within each standardized quadrat complete the following steps:

Step1. Photographs

⇒ Take photographs at the quadrats 5 m, 25 m, and 45 m along each transect and quadrats of particular interest (eg turtle grazing, high algal abundance, seagrass disturbance from boats). Photos should be taken before other measures to avoid disturbing the site. Digital images are easier to process but saltwater environments are not good for electronic cameras, disposable cameras are preferable or waterproof housing and storage bags needed for digital equipment.

⇒ Place the quadrat labeler beside the quadrat indicating locality, site number, transect and quadrat code on it.

⇒ Take the photo from as vertical position as possible while including the quadrat label and frame. Avoid shadows and reflections.

⇒ An alternative to still photos are videos which are becoming more popular in marine sampling, using a camera with underwater housing. Videos can be played back and compared through time. Images must be properly archived.

Step 2. Describe sediment composition

⇒ Describe the surface sediment in the first 1 cm based on grain size:

⇒ Mud – fine grain smooth and sticky

⇒ Fine sand – smooth but some roughness not sticky

⇒ Sand – rough grainy texture, particles distinguishable

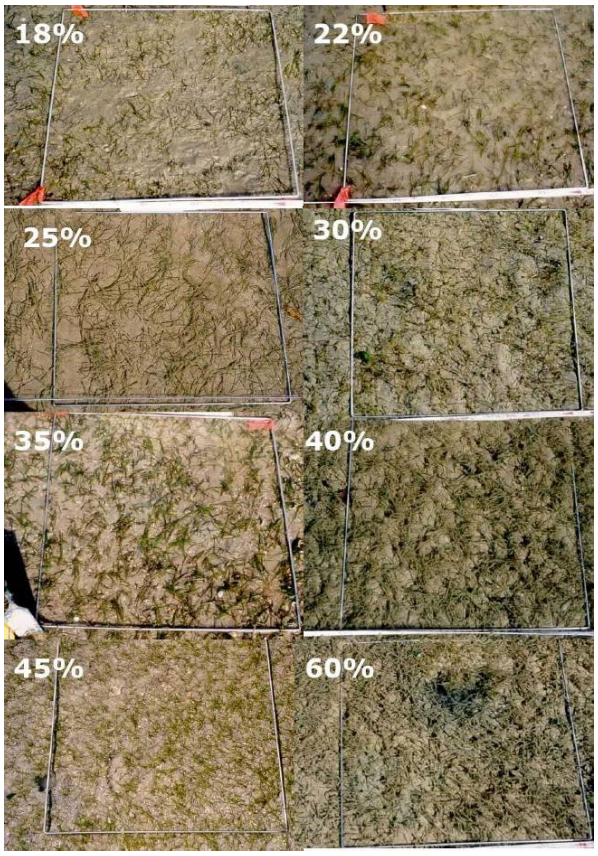
⇒ Coarse – coarse sand particles loose

⇒ Gravel – very coarse texture with small stones

Step 3. Estimate seagrass percent cover

⇒ Determine total cover of seagrass within the quadrat – use the percent cover photo standards as a guide

An Example of Seagrass Percent Cover



Step 4. Estimate Seagrass species composition

⇒ Identify the species of seagrass within the quadrat; determine the percent contribution of each species to total cover. Remember total cover must add up to 100%, e.g. species 1 = 20 %, species 2 = 45 %, bare substrate = 35%.

⇒ Use seagrass identification key (if not available a photo guide to seagrasses should be prepared).

Step 5. Measure canopy height

⇒ Randomly select 3 to 5 leaf blades from separate plants and measure the length of each in centimeters from the substrate to the leaf tip.

Step 6. Measure epiphytic algae cover

⇒ Determine the percentage cover of algal epiphytes on seagrass blades. Estimate how much of the total seagrass surface area is covered by epiphytic algae.

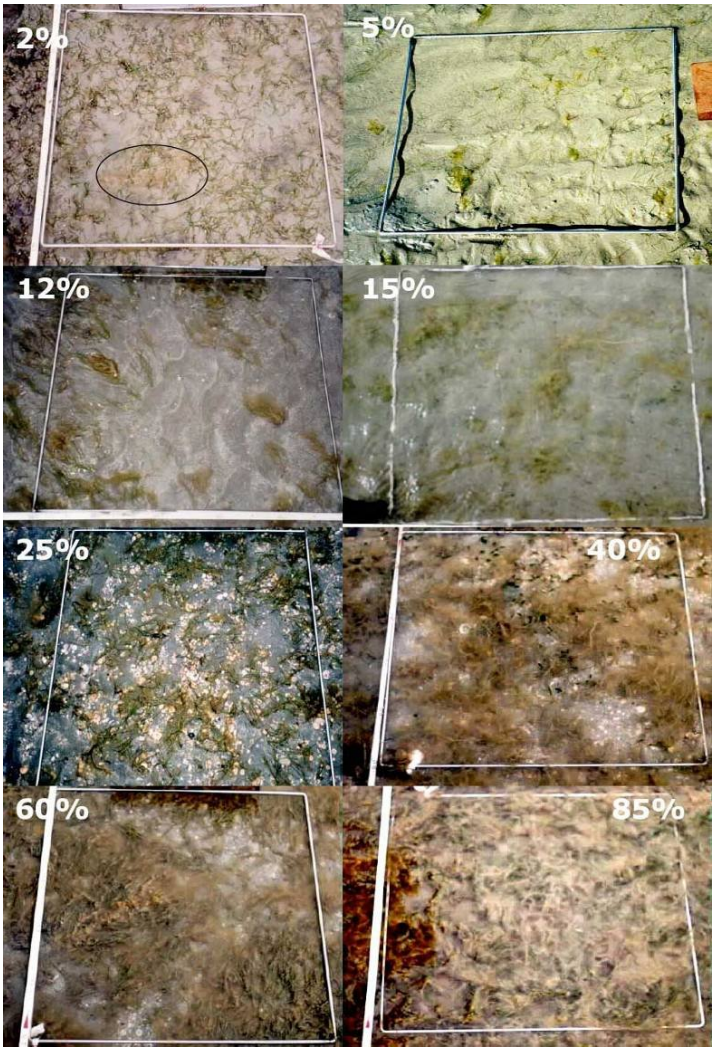
Step 7. Estimate algae percent cover

⇒ Estimate the percent cover of non-epiphytic algae in the quadrat, using the same visual technique used for seagrass cover. Non-epiphytic algae are those plants that are not attached to seagrass but may cover or overlie the seagrass blade.

Step 8. Record additional observations

⇒ Record additional observation such as rapid die back of seagrass, feeding trails or the effects of boats.

An example of Algae percent cover



Step 9. Take a voucher seagrass specimen

⇒ A collection of seagrass vouchers is best practice for ensuring correct identification particularly of species that are difficult to identify. Vouchers should be stored in appropriate conditions.

⇒ Collect only a small but complete sample (that is the whole plant including rhizomes and roots)

⇒ Store in plastic bag with waterproof label of site location, transect and quadrat number

⇒ Plants need to be refrigerated no longer than 2 days

⇒ Then pressed and dried like is done with terrestrial plants.

2) Water Quality Monitoring

Excessive nutrient enrichment stimulates epiphytic, planktonic and macroalagal growth reducing the amount of available light that can reach seagrasses (and corals) and thereby reducing seagrass growth, maximum depth of distribution and ultimately survival.

Suspended solid concentration in the water column is an important water quality indicator because of its effect on water transparency and the smothering effects suspended sediments can have on seagrasses, coral and other benthic communities. Suspended solids consist of inorganic material such as clays and organic material such as living phytoplankton. Suspended solids reduce the depth to which sunlight can penetrate, thereby reducing the habitable zones for seagrasses and corals. Reduction in light penetration has also been implicated as a major cause of decline in submerged aquatic vegetation in recent decades. Sedimentation on corals has also been implicated as a major cause of coral death close to the mainland.

Monitoring questions:
Where are phytoplankton blooms and macroalgal growth a major problem?
Where are the major areas of low dissolved oxygen waters in Mauritius and Rodrigues?

Coastal Monitoring Program

Fixed monitoring sites are to be established in areas of concern such as Grand Baie, Palmar, Pereybere, Port Louis and La Surcouf, as well as control sites in more pristine areas such as Le Morne. At each locality, three collection sites need to be established. At each site, measurements of salinity, dissolved oxygen, temperature, pH and water transparency, are

made. Water samples are collected at one of two depths in both surface and bottom waters to provide representative samples from the water column. These water samples are then chemically analyzed for nitrogen, phosphorus, carbon and silica constituents, total suspended solids and chlorophyll, which is a measure of phytoplankton biomass.

The recommended frequency of water column sampling is monthly. In smaller tributaries, the frequency of sampling is intended to provide reliable estimates of seasonal changes in water quality and provide a measure of variability within seasonal time frames.

Measuring sewage in seagrasses

Sewage effects on seagrasses can be detected by measuring level of nitrogen stable isotopes in seagrass tissue (reference). Atmospheric N generally occurs in two stable forms ^{14}N (the most abundant) and ^{15}N. Sewage is generally enriched with ^{15}N. The ratio of ^{15}N to ^{14}N is referred to as the $\delta^{15}N$ signature, which occurs in elevated levels in waters enriched by sewage. Marine plants incorporate the signature of the source in their tissues, and by examining their tissues, information on the source, extent and fate of sewage can be determined. The ability to undertake this convenient and rigorous form of monitoring would depend on in-country capacity and/or establishment of adequately capitalised environmental laboratory facilities utilised by properly trained technicians.

If blooms are detected, phytoplankton (algal, diatom, cyanobacterial) counts and identification may be required. Visual sightings of blooms can form part of the monitoring program.

CORALS

Main pressure

Coral reef communities in Mauritius and Rodrigues are impacted by a number of pressures and threats : 1) physical damage from trampling and boats, 2) over-fishing impacts on trophic hierarchies; 3) nutrient enrichment of coastal waters and associated algal growth; 4) global atmospheric pollution leading to coral bleaching during high sea surface temperature events, and 5) higher suspended sediment loading from increases in up-river soil erosion

Monitoring targets: Coral Reef Community Health & Water quality

1) Coral Reef Community Health

The Albion Fisheries Research Centre is currently monitoring coral reef community health. The monitoring program follows the standardized reef monitoring protocols outlined in the AIMS - Survey Manual for Tropical Resources (English, Wilkinson & Baker, 1997).

Reef monitoring program

Fixed transect sites have been established in 14 study areas, with 32 transect stations established across these areas.

The substrate cover and type are recorded along the transect line and the basic lifeform categories and substrate cover, immediately under the transects are recorded. The genera of the various life forms encountered are also recorded. Fish and invertebrates, such as urchins, sea cucumbers and crown-of-thorns starfish are counted within a belt of 5 m over the transect. The collected data are processed using COREMO II software.

Macro algae cover is recorded but there does not appear to be any monitoring of epiphytic algae cover on corals. Epiphytic algae compete will corals and may inhibit coral larvae establishment and recruitment in areas where corals have bleached.

Locations of Reef Monitoring Programs by Albion Fisheries Research Centre

No.	Location	No. of Stations	Reef type	Station location
1	Albion	2	Fore-reef and back-reef	West North West
2	Montagne Jacquot	3	Reef crest, 10 m & 19 m	Sewage Outfall
3	Point aux Sable	2	Fore-reef and back-reef	West North West
4	Baie du Tombeau	2	Fore-reef and back-reef	North West
5	Trou aux Biches	2	Fore-reef and back-reef	North North West
6	Anse La Raie	2	Shore and back-reef	North
7	Poudre d'Or	2	Back-reef	North East
8	Belle Mare	2	Back-reef	East
9	Trou d'Eau Douce	2	Shore and back-reef	East South East
10	Bambous Virieux	2	Shore and back-reef	South East
11	Bel Ombre	2	Shore and back-reef	South
12	Ile aux Benitiers	3	Shore, back- and fore-	South South West
13	Blue Bay Marine Park	5	All 5 within lagoon	South South East
14	Balaclava Marine Park	7	4 back-reef and 3 fore-reef	North West

2) Marine Water Quality

The Albion Fisheries Research Centre is monitoring lagoonal water quality at 21 specific study sites along the coast of Mauritius. Monitoring of physico-chemical parameters are carried out on a monthly, quarterly and bi-annually basis. Water samples are analysed for trace metals from 8 estuaries around the island bi-annually. Water quality is also monitored monthly for total and faecal coliform bacteria at 13 selected recreational beaches and 2 Marine Parks for public health aspects.

Constraints to Monitoring

The main constraints faced by the Albion Fisheries Research Centre are the following:

- ⇒ Shortage of staff for field work
- ⇒ Lack of training and upgrading of skills for technical staff
- ⇒ Present staff have to handle many projects and issues at a time

MANGROVES

Main pressure

The main pressure on mangroves is deforestation due to coastal development and the potential loss of suitable habitats.

Monitoring targets: maps of mangrove distribution & recruitment

1) Mangrove Distribution

Regional maps of mangrove distribution across Mauritius and Rodrigues are an important first step to long-term monitoring of this habitat. Distribution estimates can be determined from an analysis of time-series of calibrated TM/ETM imagery. Field verification is necessary to ensure data quality. Local-scale studies monitoring high priority sites can be undertaken to ensure that mangrove recruitment is ongoing (Plate 3).

2) Mangrove Recruitment

Fixed transects are recommended for monitoring mangrove dynamics (recruitment, growth and mortality). Sites are to be monitored yearly. A minimum of three transects are to be established at each site. As with seagrass monitoring, three parallel transects of 50 m in length with a minimum distance of 25 m apart running perpendicular to the shore are to be set. Mangrove seedling recruitment will be counted within 2 m of either side of the transect tape. As each seedling is encountered its distance along the length of the transect is recorded. Seedling and tree height and survival needs to be monitored.

Establishing the permanent transects

Necessary materials & equipment

- GPS
- Compass
- Labelled star pickets or fencing posts
- Mallet
- Plastic labels
- Cable ties

The monitoring permanent quadrats should be established using the same methodology as stated above for seagrass monitoring.

When suitable sites have been found, transect sites will need to be permanently marked. In order to reduce the amount of equipment left in the field and to reduce the attention it might attract only the central transect will be permanently marked.

⇒ Knock a plastic star picket into the ground leaving 10 cm above the substrate surface.

⇒ Attach a plastic label to the star picket that states the government department undertaking the monitoring. The site tag is marked with a code signifying the location, the site number and the transect number. The transect number on the permanent star picket will always be "2", because only the middle transect is being marked.

⇒ Record the coordinates of the transect point using the GPS (Global Positioning System).

⇒ Using a compass determine the bearing of the coastline and then determine the perpendicular bearing out to sea (add/or subtract 90 degrees to the coastal direction). Record the bearing on the data sheet.

- ⇒ Attach a 50 m measuring tape to the star picket and gaze at a fixed point out to sea on the bearing and walk until the end of the tape. At the end of the transect check the original marker is along the bearing.
- ⇒ Knock in another star picket leaving 10 cm above substrate level
- ⇒ Attach a second site marker tag to the top of the picket with cable ties.
- ⇒ Establish transects 1 and 3. They will lie 25 metres to the left and right, respectively of the origin of transect 2.

Transect Monitoring

- ⇒ Locate central marker and lay 50 m tape between star pickets in Transect 2
- ⇒ Establish Transects 1 and 3 by measuring 25 m to right and left of star pickets at 0 m and 50 m
- ⇒ Mark the start and end of transects using plastic pegs and lay 50 m tape between tent pegs ensuring that the bearing is identical to Transect 2.
- ⇒ Lay and secure all three 50 m tapes with plastic pegs to begin.
- ⇒ Record start time and within 2 m distances on either side of the transect, count all seedlings and trees, recording distance along the 50 m transect. Measure height of live plants and note any plant that is dead. Record end time for the transect and move to other transects.

INTERTIDAL MUDFLATS

Main pressures

The main pressure on intertidal mudflats is coastal development that results in changes to the physical structure of the mudflats, the estuary water flow or causes pollution to this environment.

Monitoring targets: maps of intertidal mudflat distribution and sediment quality and depth

1) Intertidal mudflat distribution

Regional maps of mudflat distribution across Mauritius and Rodrigues are an important first step to long-term monitoring of this habitat. Maps will provide information on the extent and natural dynamism of the habitat. Distribution estimates can be determined from an analysis of time-series of calibrated TM/ETM imagery. Field verification is necessary to ensure data quality. Mapping may occur in association with mangrove forest monitoring and is recommended on a 5-year cycle, unless field observation identifies rapid change in the environment.

2) Sediment analysis

The integrity of mudflats depends on their unique sediment-based trophic food webs and the role that these play in sustaining vertebrate communities, such as crustaceans and shore-birds that are dependent on the availability of these areas. Contamination of sediments can threaten the integrity of these sites and periodic monitoring of sediment composition is required to detect stressors that can threaten their ecological integrity. The main physical and chemical parameters to be monitored should target detection of changes in:

⇒ Particle size distribution

Indicator of changes in the erosion-deposition dynamics of the coastal foreshore. An increase (decrease) in particle size can indicate an increase (decrease) in the amount of energy shaping the system related to coastal development, cyclone response and longer-term trends in climatic conditions

⇒ Chemical status

Chemical analysis of samples for total nitrogen, phosphorus and organic content

⇒ Biological productivity

Assessment of changes to macro-benthic community (body size > 0.5mm)

COASTAL FRESHWATER MARSHLANDS

Main pressures

There are two main pressures on coastal marshes in Mauritius: habitat loss from backfilling and fragmentation; and declining water and habitat quality from adjacent land use and exotic species invasion.

Monitoring targets: coastal marshland habitat loss, solid waste dumping & habitat quality decline

Typha domingensis *dominated in coastal marshland in Mauritius.*

1) Coastal marshland habitat loss

The aim of this monitoring project is to inspect coastal marshland for backfill and rubbish dumping. In each of the major coastal marshlands in Mauritius, permanent monitoring sites will be established in areas where access can be easily gained to the site. If there is only a single access point then only a single photo monitoring point is required. If there are multiple access points

then multiple photo monitoring points will be required. Management actions to prevent future habitat loss may require fencing access points to stop traffic from entering the site.

Establishing the permanent photo monitoring points

Necessary materials & equipment

- GPS
- Digital camera
- Labelled star pickets or fencing posts
- Mallet
- Portable signpost (whiteboard (with markers) or clipboard with white paper and black marker pens).

Photo Monitoring Points

⇒ Two permanent markers are established in the marshlands where there is road access and the possibility of waste dumping.

⇒ The permanent markers are star pickets or fencing posts that are established at a set distance of 10 m apart.

⇒ The photographer stands at one marker and aims the camera at the other marker focusing on the marshlands behind it. The marker within the photo frame is set close to the high water edge of the marshland. A signpost is attached to the star picket that states date and site number.

2) Marshland water quality and biological monitoring

Fine-scale monitoring of water quality and biological parameters should be undertaken in a selection of marshlands of high conservation value or management concern. As with the marine environment, water quality is an essential feature of freshwater ecosystems. Excessive nutrient enrichment

and suspended solids will have significant negative impacts on marshlands, and these systems needs to be monitored to ensure these levels are maintained in low levels. Algae are considered the best indicators of nutrient enrichment in open water. Marshland depth is another important factor that characterizes marshland condition and environmental change.

Water quality monitoring program

- ⇒ At each marshland, a minimum of four fixed water-quality monitoring sites need to be established – e.g. these can be at the four cardinal points of the wetland (N, S, E, W). For very large marshlands, it would be appropriate to have a higher number of sites.
- ⇒ At each site, measurement of water depth, salinity, dissolved oxygen, temperature, pH and water transparency, are made.
- ⇒ Water samples are collected at one of two depths in both surface and bottom waters to provide representative samples from the water column. These water samples are then chemically analyzed for nitrogen, phosphorus, total suspended solids and chlorophyll a (a measure of phytoplankton biomass).
- ⇒ The minimum sampling should occur twice a year at the end of the dry and wet seasons, to provide a measure of variability within seasonal time frames.

Biological monitoring program

Biological monitoring in marshland communities aims to identify the threats and needs of both the terrestrial and the aquatic biological communities.

Necessary materials & equipment

- GPS
- Digital camera
- Ekman grab and/or dredge

Terrestrial environment:

1) Rare and threatened native species: the survival and recruitment of rare and threatened plant and animal species that contribute to the terrestrial diversity of these marshlands.

- ⇒ In the case of plants, target species need to be marked, mapped (with GPS coordinates) if close to road access fencing may need to be considered.
- ⇒ In the case of native animal species, if these are rare and hard to find it is considered a more effective use of resources to concentrate on management of habitat quality rather than searching for rare species.

2) Rich native plant communities: Monitor alien plant invasion or other disturbance activities in high priority conservation areas.

- ⇒ Identify main alien species and map their distributions in high priority conservation areas
- ⇒ Depending on the invasiveness and incidence of localized disturbance such as grazing, mapping could be done on an annual or biennial basis.

Aquatic environment:

Little is known about the biological diversity of aquatic ecosystems in Mauritius. Benthic macro-invertebrates are a biological assemblage that is widely used in aquatic monitoring programs because they are susceptible to the degradation of water quality and habitat.

- ⇒ Sampling is to be undertaken at maximum water height.
- ⇒ At each coastal marshland, a minimum of four fixed monitoring sites need to be established – e.g. these can be at the four cardinal points of the marshland (N, S, E, W). For very large ones, it would be appropriate to have a higher number of sites.
- ⇒ A standardized sampling method should be used such as an Ekman Grab (for targeting infauna) &/or a dredge for epibenthos;

RIVERS AND STREAMS

Main pressures

The riparian ecosystems of Mauritius and Rodrigues encompass both the aquatic and terrestrial habitats. The main pressures on these ecosystems include: solid waste dumping, declining water quality and aquatic communities from water extraction, pollution and nutrient enrichment, and the loss of terrestrial native habitat from clearing and alien plant and animal invasion.

Monitoring targets: Solid waste dumping, water quality & riparian vegetation cover

1) Solid Waste Dumping

Solid waste dumping in rivers and streams is a serious environmental and domestic security problem in Mauritius. The types of wastes are generally domestic sources including large items such as fridges, furniture, garden and construction debris. This activity not only degrades the riverine ecosystem it reduces the water catchment and flow of the rivers resulting in increased flooding during heavy rains. The monitoring aim of this activity requires identifying the problem areas and ensuring the wastes are removed. Waste removal will improve water quality, and maintain the scenic beauty of these attractive ecosystems.

Identifying target areas

Rivers and streams close to urban areas and public roads will need to be inspected for solid wastes. Photographs of problem areas will be taken to monitor restoration activities. Once areas have been rehabilitated vehicle access will need to be restricted.

Necessary materials & equipment

- GPS
- Digital camera
- Portable signpost (whiteboard (with markers) or clipboard with white paper and black marker pens)

2) River Water Quality

The Central Water Authority is undertaking fine-scale monitoring of water quality and some biological parameters in all major rivers and some tributaries on Mauritius. Fixed water quality monitoring points occur along the stretch of each stream. Water quality parameters are being measured on a quarterly basis.

Water quality monitoring program

⇒ Along the stretch of each stream, fixed water-quality monitoring sites have been established, above and below possible pollution point sources.

⇒ Water samples are collected only on the surface. There is no sampling of bottom waters which may have different water quality.

⇒ Water quality parameters being analyzed include the following: total coliforms, *E. coli*, free chlorine, total suspended solids, reactive phosphorous, colour, temperature, chemical oxygen demand, biochemical oxygen demand, chloride, sulphate, ammoniacal nitrogen, nitrate, nitrate as N, pH, aluminium, conductivity and turbidity.

⇒ Chlorophyll-α is a measure of phytoplankton biomass and is not being monitored because the Central Water Authority does not have the necessary analytical facilities. It is considered a very important biological parameter for the detection of eutrophication of waters and is recommended.

⇒ The sampling occurs on a 4 – 6 week basis.

⇒ A monitoring program designed to answer questions about pollution requires paired study streams of similar size that includes the a) polluted site (close to a major stream or township) and b) a control site that is adjacent to natural habitat or low density residential (avoid intensive agricultural areas which may have high fertilizer levels).

Location of River Monitoring Programs

River Locality	No. of Samples	Region
1. Rivière Dragon – Batimarais	1	South
2. Rivière du Poste	4	South
3. Rivière des Anguilles	2	South
4. Rivière La Chaux	4	South
5. Rivière des Créoles	3	South
6. Canal Naturale –Alcodis	1	South
7. Rivière du Poste de Flacq	4	East
8. Grande Rivière South East	2	East
9. Rivière Sèche	3	East
10. Rivière du Mesnil	3	Center
11. Rivière Plaine Wilhems	2	Center
12. Rivière Moka	2	West
13. Rivière Profonde	2	Center
14. Rivière Cascade	3	North
15. Rivière Terre Rouge	3	North
16. Rivière Larbourdonnais	3	North
17. Rivière du Tombeau	2	North
18. Rivière Calebasses	2	North
19. Rivière Citron	2	North

Biological monitoring program

Little is known about the biological diversity of aquatic ecosystems in Mauritius other than a few groups like the freshwater mollusks (Griffiths and Florens 2006).

Necessary materials & equipment

- GPS
- Digital camera
- Ekman grab and/or dredge

Benthic macro-invertebrates are a biological assemblage that is widely used in aquatic monitoring programs because they are susceptible to the degradation of water quality and habitat.

- ⇒ Sampling is to be undertaken at maximum water height
- ⇒ Biological sampling for macro-invertebrates will be undertaken at each site where water quality sampling is undertaken by the Central Water Authority.
- ⇒ A standardized sampling method should be used such as an Ekman Grab (for targeting infauna) &/or a dredge for epibenthos;

3) Riparian vegetation distribution and quality

Riparian vegetation plays a crucial role in maintaining bank stability, controlling bed erosion and reducing the amount of sediment and pollution entering streams. Therefore, adequate riparian vegetation cover can be directly linked to water quality issues. Maps of riparian habitats are the most important initial information for assessing the extent of riparian terrestrial habitat and for designing management and monitoring programs.

Riparian vegetation monitoring

Riparian vegetation needs to be assessed along the reach of key sites. The monitoring program needs to examine the width of the riparian zone, the proportion of the vegetation that is native and the extent and severity of riparian land clearing. Maps will provide information on the extent and dynamism of the habitat. Distribution estimates can be determined from an analysis of time-series of calibrated TM/ETM imagery. Field verification is necessary to ensure data quality. Mapping may occur in association with forest monitoring and is recommended on a 5-year cycle, unless field observation identifies rapid change in the environment.

LAKES AND RESERVOIRS

Most lakes and reservoirs are being utilized for drinking water, recreation and agricultural uses. Water quality and supply are important issues associated with these systems. Biological communities associated with these freshwater ecosystems are poorly known.

Monitoring targets: Water quality monitoring, aquatic communities & remnant vegetation communities surrounding the lakes and reservoirs.

1) Water Quality Monitoring

Water quality monitoring program

Fixed water-quality monitoring sites have been established in reservoirs of domestic water supply by the Central Water Authority.
The same parameters are monitored using the same protocol as described under the section water quality monitoring program for rivers.

Location of Reservoir Monitoring Programs

No.	Reservoir Locality	No. of Samples	Region
1.	La Ferme	3	West
2.	Mare aux Vacoas	1	South
3.	Piton du Millieu	1	Center
4.	Midlands Dam	1	Center
5.	La Nicolière	2	North
6.	Riche en Eau	1	South

2) Aquatic and surrounding terrestrial community health

Necessary materials & equipment

- GPS
- Digital camera
- Ekman grab and/or dredge
- Terrestrial community monitoring equipment (see 'native remnant habitats' section)

Biological monitoring program

The biological diversity of aquatic ecosystems in Mauritius are generally poorly known.

Benthic macro-invertebrates are a biological assemblage that is widely used in aquatic monitoring programs because they are susceptible to the degradation of water quality and habitat.

- ⇒ Sampling is to be undertaken at maximum water height.
- ⇒ Biological sampling for macro-invertebrates will be undertaken at each site where water quality sampling is undertaken by the Central Water Authority.
- ⇒ A standardized sampling method should be used such as an Ekman Grab (for targeting infauna) &/or a dredge for epibenthos;

Bassin Blanc and Mare Longue, and to a lesser extent Grand Bassin, Midlands Dam (Mt Lagrave), Mare aux Vacoas and Piton du Milieu, have some adjacent terrestrial native vegetation comprising many endemics and/or threatened species that need to be preserved therefore monitored. Monitoring of such habitats is described under the section 'native remnant habitats'.

The few natural lakes (e.g. Bassin Blanc) is habitat to aquatic native snails and water birds like the green heron. They also harbour introduced fish species.

UPLAND MARSH

Main Pressure

The upland marshlands are physically and compositionally different to the lowland marshlands. Heath communities with sedges, screwpines (*Pandanus* spp.), grasses and ferns predominate the more natural communities whereas plantations and naturalised exotic tree and grass species are prominent in the invaded communities. Threats to these communities are from invasive species and the possible future conversion for water storage facilities.

Monitoring target: alien invasions and management practices

1) Invasive species

Alien plants invasions and their removal is the priority for management of upland marshlands. The monitoring aims are to 1) identify priority areas for alien plant removal based on the following measures: species invasiveness, habitat vulnerability and native habitat/species rarity; 2) to monitor weeding practices to ensure effective removal and an efficient use of resources.

Identifying priority areas for weed management

Upland marshland will need to be examined and the proportion and extent of native vegetation assessed. Distribution estimates and vegetation maps need to be prepared from aerial photography or calibrated TM/ETM imagery, or from ground inspections. Field verification is necessary to ensure data quality. Mapping is recommended on a 5-year cycle, unless field observation identifies rapid change in the environment.

Invasive alien plants mapping

Highly invasive species are to be mapped using a quantitative approach. The % cover of weed invasion in each stratum of the plant community – canopy, mid-storey, and ground cover is determined within a specified

range and an index weighting then applied to give a final weed class, which is easily compared spatially and temporally. The steps undertaken to calculate the weed class within a specified area are listed below.

Step 1.

If in forest, visually divide the vegetation community into logical sections (ie. canopy, mid & ground storey). Define these divisions on the work sheet, and be consistent in their use within the same habitat type.

Step 2.

Estimate the percentage of weeds compared to native species within each division. Within each division, record the corresponding scale of 1 – 5. Refer to the table below.

Weed cover scale

Weed Cover %	**Scale**	**Structural Division**		
		Upper	Middle	Lower
< 10 %	1			
10 – 25 %	2			
25 – 50 %	3			
50 – 75%	4			
75 – 100%	5			

Step 3.

The weed class is calculated from the recorded scales of each division (Step 2) to give an overall rating. This calculation takes into account the impact the weeds have on the vegetation community. Weeds in the upper division or upper stratum can strangle, destroy or shade the dominant native species. Larger individuals of weed species can be considered ecologically

dominant because they can produce large quantities of seed. Weeds in the middle division generally compete with native species whilst weeds in the lower division can significantly alter ground conditions, hindering the regeneration of native species. Therefore a weighting factor is applied to each division to represent the relative impact on the vegetation community.

The equation:

Structural Division	**Weed Scale (Step 2)**	**Weighting Factor**	**Subtotal**
Upper		X 0.5	
Middle		X 0.2	
Lower		X 0.3	
Total			

The overall rating is a weed class, which illustrate the impact the weeds are having on the vegetation community.

Assessing weed removal efficiency

Monitoring weeding is a critical part of the alien plant management program. The weed management program needs to be heavily committed to the results of monitoring program, which aims to increase the impact of their weed removal efforts. The monitoring program needs to address the following issues:

1) Is the weed management program the most appropriate for the weed species, the habitat and the available resources?

2) Is actual weed removal program following the management objectives?

3) Are herbicides being used with the appropriate expertise? (concentrations are appropriate, applications are occurring at the

optimal time, herbicide painting techniques are occurring immediately after stems are cut).

4) Do we need to increase training in effective herbicide use?

5) Do we need to test different weed removal techniques to see what is the most effective? (e.g. ring barking without herbicide application efficiently control certain species).

Establishing the permanent transects to assess weed removal

Necessary materials & equipment

- GPS
- Compass
- Labeled star pickets or fencing posts
- Mallet
- Plastic labels
- Cable ties

When suitable sites have been found, establish 3 permanently marked transect sites as explained in the 'seagrass monitoring' section.

Transect Monitoring

⇒ Locate central marker and lay 50 m tape between pickets in Transect 2

⇒ Establish Transects 1 and 3 by measuring 25 m to right and left of pickets at 0 m and 50 m

⇒ Mark the start and end of transects using plastic pegs and lay 50 m tape between pegs ensuring that the bearing is identical to Transect 2.

⇒ Lay and secure all three 50 m tapes with plastic pegs to begin.

Record date, within 2 m distances on either side of the transect, count all alien and native saplings (50 to 130 cm high) and record

CAVES

Main pressure

Threats to caves in Mauritius and Rodrigues include physical damage to the structure from direct and indirect human activities such as: rubbish dumping and pollution, closure (internal or the entrance), siltation and vandalism. The second major concern is any increase in the collection of the near-threatened Mascarene Swiftlet nests for consumption, or vandalism. There is no current data that indicates an increase in the consumption of Mascarene Swiflet nests, therefore no specific monitoring program is recommended for this species at this time. The section of caves for permanent photo monitoring points should include swiflet nesting caves if feasible.

Monitoring targets: Cave Pollution and Physical Damage

1) Cave Habitat Loss

The aim of this monitoring project is for annual or two-yearly inspections of cave entrances to report on any new activity or change to the structure. Indications of backfill, rubbish dumping, pollution and vandalism are to be recorded. As with marshlands and rivers, this activity is strongly influenced by access, therefore sites that are easily accessed or close to communities should be a priority for monitoring with permanent photo points.

Establishing the permanent photo monitoring points

Necessary materials & equipment

- GPS
- Digital camera
- Labeled star pickets or fencing posts
- Mallet

- Portable signpost (whiteboard (with markers) or clipboard with white paper and black marker pens)

Photo Monitoring Points

⇒ Two permanent markers are established at the cave entrance where there is road access and the possibility of waste dumping.

⇒ The permanent markers are star pickets or fencing posts that are established at a set distance of 10 m apart.

⇒ The photographer stands at one marker and aims the camera at the other marker focusing on the cave entrance behind it. The marker within the photo frame is set close to the cave opening. A signpost is attached to the star picket that states date and site number.

⇒ Site inspection should also include a general comment about the condition of the cave, flowing water, signs of human or animal (e.g. goats) use.

⇒ During all visits, observers should enter the cave to record the number of swiftlet nests.

STEEP SLOPES

Main pressure

Steep slopes are at risk from direct and indirect human activities that may result in the following impacts: physical (soil erosion and landslides), biological (fires, alien plant invasions, overgrazing) and scenic (unsightly constructions in areas of high scenic beauty). The monitoring programs for steep slopes should aim to identify the areas most at risk of change:

1) Areas at risk from soil erosion and landslides, requiring rehabilitation;
2) Areas most at risk of constructions;
3) Areas most degraded by fires, alien plant invasion and overgrazing requiring rehabilitation;

Monitoring targets: 1) Soil erosion & landslides, 2) construction, 3) habitat degradation

1) Landslides and soil erosion

Maps of landslides and areas of serious soil erosion are the most important initial information for assessing the extent of the soil loss, and for designing management protocols and monitoring programs. The aim of monitoring is to determine if these high risk areas are increasing in area and will require rehabilitation.

Monitoring soil erosion

Necessary materials & equipment

- GPS
- Digital camera

Using topographical data and vegetation cover prepare maps of high risk areas. Select a subset of high risk areas that are readily accessible to inspections. Visit each site and take GPS co-ordinates of the slide or erosion pathway. If possible walk part of the perimeter with the GPS so as to prepare a permanent map of the site. Take photos from fixed points and record GPS co-ordinates of photo points. Inspect every 3-5 years or after severe storms.

2) Construction on steep slopes

Monitoring the threats to the steep slopes by construction projects can be undertaken by ensuring a database is maintained of all construction proposals (residential and roads) that occur within this ESA type. Regional analysis can be undertaken to determine which localities are experiencing the greater pressures.

3) Habitat degradation

The steep slopes support habitat in a range of states from relatively intact to highly degraded. Degrading processes include: fire, invasive species and overgrazing. Monitoring programs need to initially examine the state of the steep slopes from a large-scale perspective with regional maps. This should assist in identifying priority areas to focus future fine-scale monitoring.

NATIVE REMNANT HABITATS (HIGH NATIVE CONTENT)

Main pressure

Native terrestrial habitats in Mauritius and Rodrigues occur mainly as remnant habitats in relatively inaccessible localities such as mountain tops and steep slopes. The main pressures to the high quality habitats are invasive species, deforestation, intensive grazing, and habitat and population fragmentation. Areas of conflicting land use need to be identified as high priority sites for monitoring.

High priority sites with conflicting land use objectives will require a monitoring program to assess the condition of these native remnant habitats.

Monitoring targets: Habitat loss, Invasive species

1) Habitat loss in high priority areas

Deforestation is still occurring and needs to be monitored. Regional maps of the distribution of high priority habitat including lowland forest areas are an important first step to long-term monitoring of this habitat. Distribution estimates can be determined from an analysis of time-series of calibrated TM/ETM imagery. Field verification is necessary to ensure data quality.

2) Invasive species

Alien plant invasions and their removal is the priority for management of native habitats. The monitoring aims are to 1) identify priority areas for weeding based on the following measures: weed species invasiveness, habitat vulnerability and habitat/species rarity; 2) to monitor weeding practices to ensure effective removal and an efficient use of resources.

Weed Mapping

High priority weeds are to be mapped using a quantitative approach. The % cover of weed invasion in each stratum of the plant community – canopy,

mid-storey, and ground cover is determined within a specified range and an index weighting then applied to give a final weed class, which is easily compared spatially and temporally. A detailed description of the steps undertaken to calculate the weed class within a specified area are listed in the 'invasive alien plants mapping section'.

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Assessing weed removal efficiency

Monitoring the weed removal process is a critical part of the weed management program. The weed management program needs to be heavily committed to the results of monitoring program, which aims to increase the impact of their weed removal efforts. The monitoring program needs to address the following issues:

1) Is the weed management program the most appropriate for the weed species, the habitat and the available resources?
2) Is actual weeding program following the management objectives?
3) Are herbicides being used with the appropriate expertise? (concentrations are appropriate, applications are occurring during the plant growing season, herbicide painting techniques are occurring immediately after stems are cut).
4) Do we need to increase training in effective herbicide use?
5) Do we need to test different weed removal techniques to see what is the most effective?
6) Weed removal and habitat restoration may be a more effective use of conservation resources.

Establishing the permanent transects to assess weed removal

Necessary materials & equipment

- GPS
- Compass
- Labeled star pickets or fencing posts
- Mallet
- Plastic labels
- Cable ties

When suitable sites have been found, establish 3 permanently marked transect sites as explained in the 'seagrass monitoring' section. Prioritise the sites at risk of invasion based on the weed species, habitat vulnerability and habitat rarity.

3) Deer overstocking and weed invasion

Finding a tenable balance between livestock density and native flora can depend on many factors that are often difficult to control. Severe over-grazing of native regeneration, trampling of the ground flora and de-barking of larger plants facilitate the invasion of weed species. Therefore a monitoring program that evaluates how different deer stocking rates in similar forest communities affects the invasion of weed species will be critical to determine what density of deer stocking is compatible with objectives of biodiversity conservation.

PATROLLING & ENFORCEMENT

Monitoring ESA integrity will invariably prove to show that some sites are degrading in the face of unapproved dumping, effluent dishcharge and land-use modifications. In instances where this is the case, cease-and-desist notice has been delivered, but activities continue unabated, it may be necessary to enforce provisions more strenuously. In this instance, the ***Police de l'Environnement*** should be engaged to investigate and apprehend those responsible for site degradation and prevent further activities from impacting the ESA.

Where the risk of imminent ESA degradation is 'elevated', the Police de l'Environnement should be consulted and a schedule of patrolling established until such time as further measures can be put in place to deter impermissible activities. Coordination with respect to jurisdictional authority (e.g. National Park, Nature Reserve) should be maintained in all circumstances and where cost-effectiveness can be maintained through resource-sharing and delegation to other authorities (e.g. Coast Guard for Offshore ESA Types).

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