



**MAURITIUS RESEARCH COUNCIL**

# **THE USE OF SYSTEM DYNAMICS APPROACH TO IDENTIFY INTEGRATED COASTAL ZONE PLANNING AND MANAGEMENT INDICATORS FOR MAURITIUS: A PERFORMANCE EVALUATION MODEL**

**Final Report**

*June 2013*

**MAURITIUS RESEARCH COUNCIL**

*Address:*

Level 6, Ebene Heights,  
34, Cybercity,  
Ebene,  
P.O Box: 72201  
Mauritius.

Telephone: (230) 465 1235  
Fax: (230) 465 1239  
Email: [mrc@intnet.mu](mailto:mrc@intnet.mu)  
Website: [www.mrc.org.mu](http://www.mrc.org.mu)

**This report is based on work supported by the Mauritius Research Council under award number MRC/RUN-AAP-1203. Any opinions, findings, recommendations and conclusions expressed herein are the author's and do not necessarily reflect those of the Council.**

# REPORT

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## THE USE OF SYSTEM DYNAMICS APPROACH TO IDENTIFY INTEGRATED COASTAL ZONE PLANNING AND MANAGEMENT INDICATORS FOR MAURITIUS: A PERFORMANCE EVALUATION MODEL

PRINCIPAL INVESTIGATOR: ASSOCIATE PROFESSOR (DR.) CHANDRADEO  
BOKHOREE

CO-PRINCIPAL INVESTIGATOR: DR. RANJEET BHAGOLI

JUNE 2013

# REPORT

## **The Use of System Dynamics Approach to Identify Integrated Coastal Zone Planning and Management Indicators for Mauritius: A Performance Evaluation Model**

**SCHOOL OF SUSTAINABLE DEVELOPMENT AND  
TOURISM**

**UNIVERSITY OF TECHNOLOGY, MAURITIUS**

©La Tour Koenig Pointe-aux-Sables  
Mauritius

Tel: (230) 207-5250 Fax: (230) 234-6269

## **SUMMARY**

This project relates towards developing a systemic model to support integrated coastal zone planning and management activities prevailing in Mauritius. The island is a small one with developed coastal areas that sustain the livelihoods of local inhabitants as well as its economy. There have been major developments in these areas as a result of the expansion of the fishing and tourism industries, and other coastal activities. Further, projected outcomes of global climate change comprise warmer land and ocean temperatures, rises in both sea level and acidification, changes in rainfall frequency and pattern as well as in storm severity. As a Small Island Developing State (SIDS), Mauritius is highly vulnerable to negative climate change impacts on its natural and built coastal environment, thus endangering coastal activities which require coastal resources to be perennial. Consequently, the island is faced with complex coastal zone management challenges associated with our attempt to achieve economic growth without destroying the ecological systems that support human existence. Poorly planned coastal land use including residential, agricultural and leisure activities also generate aftermaths on climate change while exacerbating coastal vulnerability. These circumstances justify an integrated coastal zone management (ICZM) whereby coastal land use planning as one of its key constituents would also combine climate mitigation and adaptation measures. The proposed model take into consideration the rising coastal issues, find out whether a systems approach may be used to address coastal zone problems and the identification of a set of indicators best describing the coastal zone to be used for monitoring and evaluating ICZM plan of actions. Flic-en-Flac as a particular demo site of Mauritius has been considered for that purpose. Data profiling and site characterization by means of a survey was carried out to determine relevant variables. A system dynamics approach using causal loop diagram has been applied to illustrate the possible relationships between the variables to generate specific indicators which will be used for scenario planning. Eventually, this exercise will help to evaluate and monitor ICZM performance of that particular demo site.

## **ACKNOWLEDGEMENT**

Sincere thanks and appreciation go to the Mauritius Research Council for the financial support provided, without which this research project would not have been possible.

Special thanks and gratitude to the University of Technology, Mauritius for having given the opportunity and appropriate support to accomplish this research work.

Thanks also go to the Research Assistant, Ms. Yashna Beeharry who has helped towards realizing this project.

Gratitude is expressed to all stakeholders who have participated and provided their valuable assistance.

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## **1.0 INTRODUCTION**

### **1.1 Project Background**

The coastlines of Mauritius have known an array of development since decades and now host a range of activities related to the fishing and tourism industries. These coastal activities are important to the economy of Mauritius. These major developments have been positively as well as negatively impacting the socio-economic environment of the coastal zones of Mauritius; causing irreversible damages to the ecosystems. Moreover, the damages caused by human development have worsened by the effects of climate change owing to the fact that Mauritius is a Small Island Developing State (SIDS). Mauritius is highly vulnerable to the negative climate change impacts on its natural and built coastal environment which is a threat to coastal activities. The implementation of an ICZM process is required in order to manage the coastal zones in a balanced way and at the same time to ensure sustainable development. Integrated coastal zone planning and management of the coastal zones of Mauritius will help in combining the mitigation and adaptation measures of climate change and also ensuring the aim of the Maurice Ile Durable (MID) project: ‘the continuous improvement of the quality of life while reducing our ecological footprint through innovation and responsible investment’.

### **1.2 Project Rationale**

Mauritius Island has a coastline of 332 km long where a range of activities related to tourism, recreation and fishing take place. These activities impact both positively and negatively on the socio-economic environment of the coastal zones. They are sources of income and sustenance for the inhabitants and improve the quality of life. On the other hand, they irreversibly damage the marine and land based ecosystems depleting biodiversity and natural resources. Moreover, this situation already aggravated by climate change is likely to deteriorate if appropriate mitigation and adaptation measures are not taken. There is therefore an increasing need to initiate an ICZM process in order to ensure balanced management and sustainable development of these zones. One of the outcomes of the project is a set of indicators applicable to the demo site through a system dynamics approach. Since, the results obtained will be simulated, this will aid in testing and weighing the indicators thus reflecting the underlying structure of the prevailing system. These indicators may then be used as a reference for the evaluation and monitoring of ICZM in this particular site both on a short and long term basis. Literature has demonstrated that

monitoring and evaluation are essential to the success of ICZM (Balt Coast, 2005; Cicin-Sain and Knecht, 1998). Monitoring aims the efficiency and effectiveness of the process of ICZM. Evaluation helps in the follow up of the set goals and strategies of ICZM (UNESCO, 2001). Monitoring and evaluation are two distinct set of activities but are related to each other. They take into consideration efficiency, effectiveness and impact of an ICZM process. System dynamic approach has been an innovative modeling technique being applied in several fields and can be well considered towards implementing successful ICZM. The system dynamic approach will help in the setting up of scenario planning and for ICZM monitoring and evaluation. Successful implementation of such a model will eventually result towards supporting key ICZM initiatives undertaken in Mauritius by the relevant stakeholders (Example: Ministry of the Environment and sustainable development and NGOs).

### **1.3 Review of Literature**

#### **COASTAL ZONES**

##### **Definition of Coastal Zones**

The coastal zone consists of a terrestrial and marine area meeting, influencing and interacting with each other. Coastal zones may be defined as the interface where land meets the sea and comprise of a range of coastal land, intertidal area, aquatic systems including the network of rivers and estuaries, islands, transitional and intertidal areas, salt marshes, wetlands and beaches (World Bank, 1996; Cicin-Sain and Knecht, 1998). Furthermore, the Mediterranean ICZM Protocol defines the coastal zone as *‘a geomorphologic area either side of the seashore in which the interaction between the marine and land parts occurs in the form of complex ecological and resource systems made up of biotic and abiotic components co-existing and interacting with human communities and relevant socio-economic activities’* (Mediterranean ICZM Protocol, 2008). There are several definitions for a coastal zone: none of them being common or unique but they complement each other and serve different purposes. Moreover, a general understanding of a coastal zone is known but it is complicated or even difficult to set landward or seaward boundaries to it. In this context, the US Commission on Marine Science has worked a general definition: *‘the part of the land affected by its proximity to the sea, and that part of these are affected by its proximity to the land as the as the extent to which man’s land-based activities have a measurable influence on water chemistry and marine ecology* (US Commission on Marine

Science, Engineering and resources, 1969). The coastal zone may be viewed as a dynamic and fragile environment consisting of interacting human and economic activities. The surprising fact of this zone is that there is a strong relation between anthropogenic activities and biotic community which cannot be found elsewhere.

### **Importance of Coastal Zones**

Coastal zones are both environmentally and economically valuable (Koshy Varghese *et al.*, 2007). Marine ecosystems thrive in nutrient rich water resulting in biological productivity which therefore sustains a unique and rich biodiversity. The location of coastal zones makes them economically valuable. Mangrove forests, estuaries, coral reefs, dunes and beaches and sea grass beds form part of the coastal ecosystems which are complex. Coastal ecosystems yield a range of goods which are consequently used for food, construction, fuel, income among others. With development of harbors, activities such as shipping, industry and tourism, coastal zones have gain even importance.

Coastal zones form part of the most ecological and socio economical system on Earth (C.D. G.Harley *et al.*, 2006). The coasts because of its aesthetic value are areas of convergence of people and human activities for recreational purposes. Historically, owing to biophysical and climatic conditions along with communication and navigation facilities, coastal areas have been a key habitat for humans. The coastal zones represent less than 15% of the Earth but are home to more than 60% of the population: 2.8 million people live within 100 km of the coast (McGinn AP., 2002). According to UNCED, 1992 and European Environment Agency, 1999, if this trend is maintained, by 2025, this figure will attain 75%. Hence, the coastal zone is a dynamic area where not only land and sea meet and interact but where there are great number of demands from environmental, economic and community sectors.

### **Coastal Zones Issues**

Demands from the different sectors of the coasts very often conflict with each other. Owing to over development of coastal zones land, there has been a degradation of the environment. The following is some of the most common issues faced within the coastal zones are:

- Sea level rise
- Dilution of the social fabric
- Coastal erosion
- Lost opportunities for durable employment

- Habitat degradation
- Land loss
- Pollution
- Oil spills
- Coral damage
- Fisheries and aquaculture
- Quality of water
- Eutrophication
- Widespread coastal erosion
- soil and water resources contamination
- Problems of water quality and quantity
- Destruction of cultural heritage
- Loss of property and development options
- Marginalization and emigration
- Inundation of coastal wetlands
- Mining of sand
- Construction of harbours
- Urban sprawling
- Urbanisation and transport
- Agriculture
- Tourism, recreation and hunting
- Industry (energy production)
- Discharge of wastewater
- Sea dumping
- Marine Protected Areas
- Loss of biodiversity
- Unemployment and social instability
- Competition between users for resources

## COASTAL ZONES IN MAURITIUS

### Definition of Coastal Zones in Mauritius

The Mauritian legislation, the Environmental Protection Act of 1991 defines a coastal zone as ‘any area of seawater including any low-tide elevation, land, beach, islet, reefs, rocks, lying between the baseline and the high water mark, or any land which is situated wholly or partly within 81.21 metres from the high water mark and includes any estuary or mouth of a river and that part of a river, stream or canal which lies within 81.21 metres from the outermost point of its bank on the sea at high tide’ (EPA,1991). Subsequently, the Environmental Protection Act of 2002 replaced the definition of the coastal zone stipulated in the EPA that of the year 1991 by a more rational one: ‘ *any area which is situated within 1 kilometre or such other distance as may be prescribed from the high water mark, extending either side into the sea or inland, including coral reefs, reef lagoons, beaches, wetlands, hinterlands and all islets within the territorial waters of Mauritius and Rodrigues, any estuary or mouth of a river and that part of a river, stream or canal which lies within 1 kilometre from the outermost point of its bank on the sea at high tide and the islands of Agalega and Saint Brandon, and other outer islets*’.

## Overview of Coastal Zones in Mauritius

The area of Mauritius is 2,040 km<sup>2</sup> and it has a coast line of 332 km long (IndexMundi, 2011). The beach authority has 95 proclaimed public beaches in Mauritius and is surrounded by 49 islets. The coastal zones of Mauritius are sources of sustenance to many inhabitants and also to the Mauritian economy. Coastal zones of Mauritius host numerous economic as well leisure activities. Furthermore, the coasts are home to many fishermen who are dependent on the fishery resources for a livelihood. The economy which was before solely dependent on agriculture has now developed owing to the rapid expansion of the touristic industry. Tourism is an economic pillar of Mauritius (CSO, 2011) which has developed within the coastal zones (FAO, 2001). According to the CSO, in 2010 and 2011 respectively, 934,827 and 964,642 tourists from different countries of the world visited Mauritius (CSO, 2011). Moreover, coastal zones are places of recreational and sports activities: submarine dives, undersea walk, diving and glass bottom boats to watch the fringing reefs and endemic fish species and unique biodiversity not only to tourists but also to Mauritians.

## INTEGRATED COASTAL ZONE MANAGEMENT (ICZM)

### ICZM

The European Commission defines ICZM as *‘a dynamic, continuous process designed to promote sustainable management of coastal zones. ICZM seeks, over the long-term, to balance the benefits from protecting, preserving, and restoring coastal zones, the benefits from minimizing loss of human life and property, and the benefits from public access to and enjoyment of the coastal zone, all within the limits set by natural dynamics and carrying capacity’* (European Commission, 1999). This definition includes the essence of integrating economic development, environmental and social aspects aiming to achieve sustainability based on a time scale for the management of the coasts. The IPCC defines ICZM as *‘an adaptive process of resource management for environmentally sustainable development in coastal areas. It is not a substitute for sectoral planning, but focuses on the linkages between sectoral activities to achieve more comprehensive goals’* (IPCC, 1994). Another definition of ICZM is *‘a management model that had its beginning in the practice of conflict resolution which was employed at regionally and local levels in the attempt to mediate dispute between coastal zone stakeholders’* (M.F. Forst, 2009). There are several definitions of ICZM but the aim is to come with a solution for the worldwide perceived problems of the coasts (Maren Lau, 2005).

From all these definition the common elements are that ICZM is a multi-disciplinary and a continued decision-making process. This process involves the participation of stakeholders to achieve the goals of sustainability, i.e. managing the coastal resources based on the social, economic and environmental aspect sand also the arising conflicts in a holistic manner (MarenLau, 2005).

### **ICZM: History and Evolution**

ICZM dates back to 1965. In the first decade of the ICZM, the United States of America, Australia and the United Nation Environmental Program (UNEP) had been the major participants in this issue. In 1992, the Earth Summit in Rio de Janeiro which recognized the coastal problems and the necessity of organizing strategic zones through an international cooperation. The table below is a summary of the history and evolution of ICZM:

**Table 1: Worldwide History and evolution of ICZM**

<b>1965</b>	Establishment of the first ICZM program through the San Francisco Bay Conservation and Development Commission)
<b>1968</b>	Stratton Commission Report, “Our Nation and Sea” A recommendation was made for the creation of a National coastal zone management Program)
<b>1972</b>	The first academic journal, the Coastal Zone Management Journal devoted to ICM was published. This name is later changed to the ‘Coastal Management Journal’
<b>1973</b>	Preparation of the Law of the Sea Treaty by the United Nations until 1982. UNEP and its Regional Seas Programme were created.
<b>1974</b>	The US National Estuaries Program within the US EPA was established.
<b>1976</b>	Protocol on Integrated Coastal Zone Management in the Mediterranean was adopted on16 February 1976 and was eventually amended in June 1995.
<b>1977</b>	Costa Rica became the first developing nation to initiate an ICM program
<b>1978</b>	First US Coastal Zone Conference (CZ’78) held in San Francisco. Eleven subsequent conferences were successively held.
<b>1982</b>	The Law of the Sea Convention was adopted by the United Nations. The process of adoption by the world’s nations begun.
<b>1983</b>	USAID became the first international assistant institution to create an ICZM program for assisting developing nations. Ecuador, Sri Lanka and Thailand were chosen for the preparation of pilot ICZM projects.
<b>1984</b>	First conference on ICZM in South and Central America was convened in Mar del Plata, Argentina.
<b>1992</b>	UN Conference on Environment and Development (UNCED) was held in Rio de Janeiro. Agenda 21 was an outcome of the conference. Chapter 17 of the Agenda 21 mainly focused on ICZM.
<b>1996</b>	The first international conference focused on the assessment of the successes and failures of ICZM efforts was held in Xiamen China
<b>1997</b>	Canada enacts the National Ocean Act European Commission (Directorate XI) which

	was an initiative of a major program on ICM
<b>2001</b>	Marine and Coastal Resources Management Project (MCRP) (2001-2006) was conducted in Indonesia. The project was funded by ADB
<b>2002</b>	In the beginning 2002, 145 countries had established 622 cases on ICZM issue in national and sub national scale

Source: modified from M. R. Islam (2008) as adapted from Sorensen, (2002)

## ICZM in Mauritius

Mauritius is a small island of an area of 2,040 km<sup>2</sup> comprising of a 332 km long coastline (IndexMundi, 2011). The key issues of the Mauritian coastal zones are the tourism activities, past sand mining, uncontrolled development in the past, illegal back filling of wet lands, unsustainable fishing practices, erosion, discharge of waste water, natural calamities such as cyclones, climate change, among others (MoESD, 2012). The Environment Protection Act 2002 (Act No. 19) makes provision for the establishment of an ICZM committee (EPA, 2002). The National Environmental Policy 2007 of Mauritius comprises of specific sections and provisions on ICZM (NEP, 2007). The Ministry of the Environment and Sustainable Development has an ICZM division whose duties are the (MoESD, 2011):

- Development of an integrated coastal management plan
- Coordination of regional and international projects
- Monitoring coastal resources including wetlands
- Control beach erosion
- Upgrading of recreational facilities (jetties, kiosks, bathing areas)
- Protection marine flora and fauna
- Management of islets and outer islands
- Preparation of guidelines for coastal construction
- Development of an oil spill contingency plan and a sensitivity map
- Monitoring of coastal water quality

Following the legislation, the Ministry of the Environment and Sustainable Development has undertaken several projects related to ICZM: coastal erosion studies, environmental risks in areas of Grand Baie and the preparation of a strategic EIA aiming to identify potential sites for marinas, ski lanes and bathing areas among others (MoESD, 2011). In 2011, a Strategic Plan for ICZM for Mauritius and Rodrigues was developed by the Ministry of Environment and



sustainable development (ReCoMaP, 2011). The management of coastal resources of Mauritius is made in close collaboration of several institutions such as the Beach Authority of the Ministry of Local Government, the Mauritius Port Authority, the Prime Minister's Office together with Ministries such as Agro – Industry, Food Production and Security, Home Affairs, Housing and Lands, Shipping and Tourism (MoESD, 2011).

## **SYSTEM DYNAMICS**

### **The System Dynamics Approach**

The system dynamics approach is to understand how things change over time (P. Hjorthet *al.*, 2005). System dynamics was developed by Jay W. Forrester in 1961 and applied to public policy and in mid-1970 in population health (Forrester J.W, 1961). The methodology of System dynamics, over the last decades has been refined and the its application is used in a range of problems such as for improvement of quality in corporation, diabetes, resource planning, management, economy, environment and other dynamic systems (P. Hjorthet *al.*, 2005). System dynamics deals with internal *feedback*-loops and time create behavior within the structure of a system (Creative learning, 2010). System dynamics may be viewed as an approach to evaluate problem based on fact the structure of a problem, i.e. the way essential system components are connected, generates its behavior (Richardson and Pugh, 1989; Sterman, 2000). This approach is appropriate to analyse problems whose behavior is governed by feedback relationships over a period of time (Vennix, 1996). Within this system, a simulation model is created which is the basis for the problem and also allows assumptions made to work explicit. Once a model is obtained, it may be used for simulation of action proposed based on a particular problem or on a whole system (P. Hjorthet *al.*, 2005). People are unable to predict how complex and interdependent systems behave and hence the need of such a tool (Forrester J. W, 1987). A system dynamics analysis proceeds through several major steps for problem solving (Ford, 1999; Richardson and Pugh, 1989):

- i. Define the problem
- ii. Describe the system
- iii. Develop the model
- iv. Build confidence in the model
- v. Use the model for policy analysis
- vi. Use the model for public outreach

In order to grasp the structures within causing the patterns within a system, graphical notation is used:

- Causal Loop Diagram (CLD) represents a closed loop of cause-effect linkages (causal links) with the aim to capture how the variables interrelate (P. Hjorth *et al.*, 2005). There are five steps to construct a CLD (James R. Burns, 2001):
  - i. Choosing variables
  - ii. Linking variables with arrows pointing from cause to effect
  - iii. Assigning a direction of effect (same or opposite) to each link
  - iv. Indicating delays
  - v. Assigning polarity to overall loop.

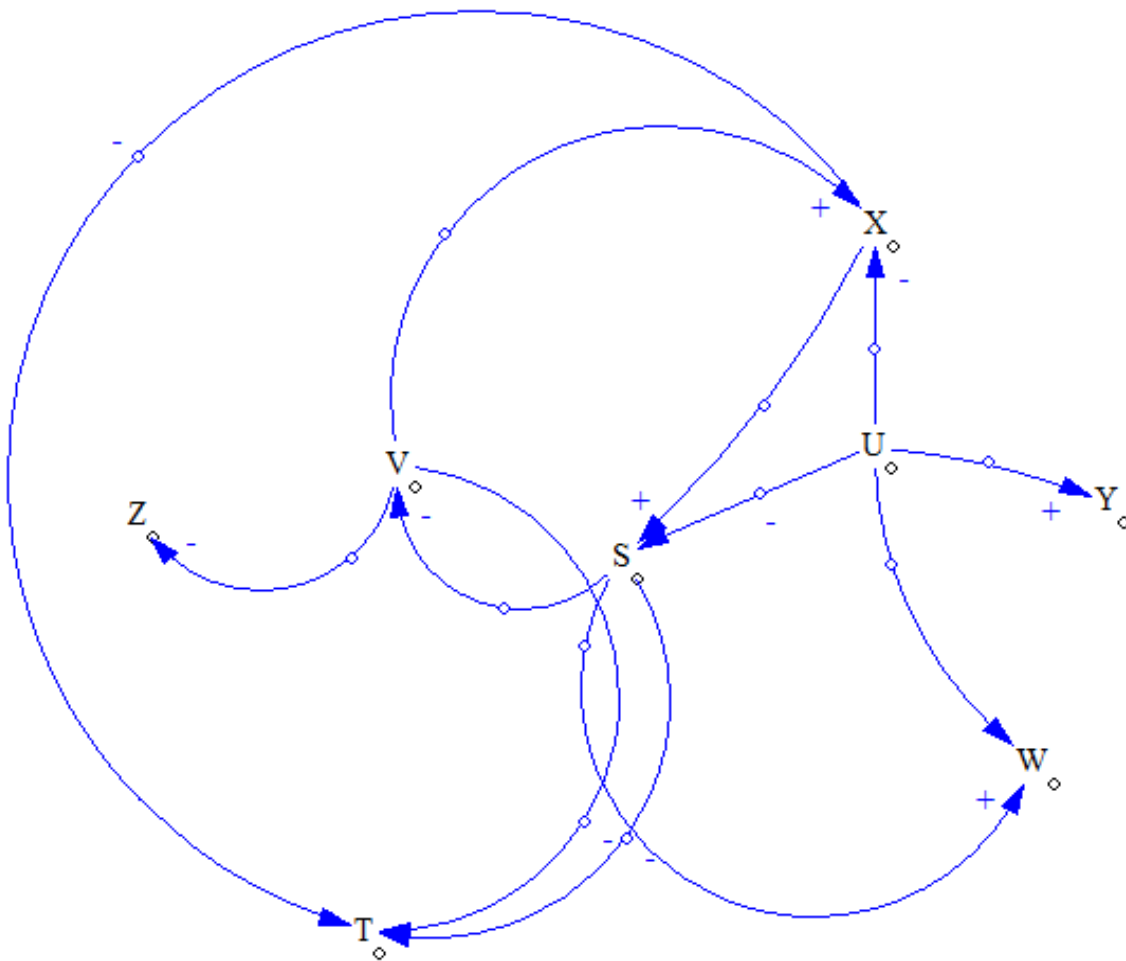


Figure 1: An illustration of a CLD

## **INDICATORS**

### **Overview of Indicators**

The English dictionary defines an indicator as “*advice that provides specific information*”. An indicator is a measure which provides a simplified view of a complex phenomenon/system in terms of processes and corresponding variables (Scottish Executive Central Research Unit, 2001). They are used in different fields such as health, economy and environment and affect all levels of the processes of decision making to quantify as well as to simplify information (Scottish Executive Central Research Unit, 2001). An indicator produces quantified information so as to help concerned actors to communicate, negotiate or make decisions (EU, 2008). No single perfect indicator or set of indicator exists but should rather be tailored based on the use (EU, 2008). Indicators are intended to provide meaningful, readily understandable information directly related to the goals of a project or specific policy (Simone, 2003). Good indicators must be theoretically well-founded and must be supported by reliable and valid data. Indicators are widely used in different sectors and disciplines. Economic and social indicators such GDP or HDI have been used for many years all over the world but environmental indicators have been developed more recently (Simone, 2003).

Indicators are derived from data and are the first basic tool for the analysis of change in society. Indicators based on proper information may be viewed as a basis to assess conditions and trends of sustainable development. They may be a basis for such assessment and formulation of policies. By combining a set of data which is simpler to interpret than complex statistics, indicators may aid communication between stakeholders (Segnestam, 2002).

### **The Use of Indicators for ICZM Evaluation and Monitoring**

Chapter 17 of the Agenda 21, the sustainable development action plan of the United Nations developed as a result of the Rio de Janeiro 1992 Earth Summit has explicitly elaborated the use of indicators for monitoring state and progress of the implementation of ICZM (Report of the United Nations conference on environment and development, 1992). The Chapter 17 is on the ‘Protection of the oceans, all kinds of seas, including enclosed and semi-enclosed seas, and coastal areas and the protection, rational use and development of their living resources’. Indicators for ICZM may be used as overlapping ways, i.e. for communication as well as for measurement (Scottish Executive Central Research Unit, 2001). Measurement of sustainable

development in coastal zones is one way of achieving the objectives of ICZM. The use of indicators is also encouraged by the ICZM Protocol for the Mediterranean (UNEP, 2008).

For the measurement of the sustainability of coastal zone development and the implementation of ICZM policies, several sets of indicators and indicators have been developed in many countries. One of the most common set of indicators is used in various European Regions (DEDUCE consortium, 2007). In May 2002, a recommendation on the implementation of ICZM was approved by the European Parliament and the Council. Following which, the work of the Working Group on Indicators and Data (WG-ID) proposed 7 groups of indicators based on 7 goals of the EU ICZM Recommendation. This was in view of achieving the goals covering the components of the coastal system for coastal sustainability set out in the EU Recommendation. WG-ID proposed a core set of 27 indicators and 46 measurements designed to monitor sustainable development of the coastal zone. This list of goals represents the theoretical framework (the model of the system) used to identify and select the indicators. These indicators aim to measure the level of sustainable development of the coastal zone.

**Table 2: EU ICZM Recommendation**

INDICATORS	MEASUREMENTS
<b>1. Goal: To control further development of the undeveloped coast.</b>	
Area of built land	- Percent of built land by distance from the coastline
Rate of development of previously undeveloped land	- Area converted from non-developed to developed land uses
Demand for property on the coast	- Size and proportion of the population living in the coastal zone - Value of residential property
Demand for road travel on the coast	- Volume of traffic on coastal motorways and major roads
Pressure for coastal and marine recreation	- Number of berths and moorings for recreational bathing
Land take by intensive agriculture	- Proportion of agricultural land farmed intensively
<b>2. Goal: To protect, enhance and celebrate natural and cultural diversity.</b>	
Area of semi-natural habitat	- Area of semi-natural habitat
Area of land and sea protected by statutory designations	- Area protected for nature conservation, landscape and heritage
Effective management of designated sites	- Rate of loss of, or damage to, protected areas
Change to significant coastal and marine	- Status and trend of specified habitats and

habitats and species	<ul style="list-style-type: none"> <li>species</li> <li>- Number of species per habitat type</li> <li>- Number of red list coastal area species</li> </ul>
Loss of cultural distinctiveness	<ul style="list-style-type: none"> <li>- Number and value of sales of local products with regional quality labels or European PDO/PGI/TSG</li> </ul>
<b>3. Goal: To promote and support a dynamic and sustainable coastal economy.</b>	
Patterns of sectoral employment	<ul style="list-style-type: none"> <li>- Full time, part time and seasonal employment per sector</li> <li>- Value added per sector</li> </ul>
Volume of port traffic	<ul style="list-style-type: none"> <li>- Number of incoming and outgoing passengers per port</li> <li>- Total volume of goods handled per port</li> <li>- Proportion of goods carried by short sea routes</li> </ul>
Intensity of tourism	<ul style="list-style-type: none"> <li>- Number of overnight stays in tourist accommodation</li> <li>- Occupancy rate of bed places</li> </ul>
Sustainable tourism	<ul style="list-style-type: none"> <li>- Number of tourist accommodation holding EU Eco – label</li> <li>- Rate of overnight stays to number of residents</li> </ul>
<b>4. Goal: To ensure that beaches are clean and that coastal waters are unpolluted.</b>	
Quality of bathing water	<ul style="list-style-type: none"> <li>- % of bathing waters compliant with the guide value of the European</li> <li>- Bathing Water Directive</li> </ul>
Amount of coastal estuarine and marine litter	<ul style="list-style-type: none"> <li>- Volume of litter collected per given length of shoreline</li> </ul>
Concentration of nutrients in coastal waters	<ul style="list-style-type: none"> <li>- Riverine and direct inputs of Nitrogen and Phosphorus to inshore waters</li> </ul>
Amount of oil pollution	<ul style="list-style-type: none"> <li>- Volume of accidental oil spills</li> <li>- Number of observed oil slicks from aerial surveillance</li> </ul>
<b>5. Goal: To reduce social exclusion and promote social cohesion in coastal areas.</b>	
Degree of social exclusion	<ul style="list-style-type: none"> <li>- Indices of multiple deprivations by area</li> </ul>
Relative household prosperity	<ul style="list-style-type: none"> <li>- Average household income</li> <li>- % of population with a higher education qualification</li> </ul>
Number of second homes	<ul style="list-style-type: none"> <li>- Ratio of first to second homes</li> </ul>
<b>6. Goal: To use natural resources wisely.</b>	
Fish stocks and fish landings	<ul style="list-style-type: none"> <li>- State of the main fish stocks by species and sea area</li> <li>- Recruitments and spawning stock biomass by species</li> <li>- Landings and fish mortality by species</li> </ul>

	- Value of landings by port and species
Water consumption	- Number of days of reduced supply
<b>7. Goal: To recognize the threat to coastal zones posed by climate change and to ensure appropriate and ecologically responsible coastal protection.</b>	
Sea level rise and extreme weather conditions	<ul style="list-style-type: none"> <li>- Number of 'stormy days'</li> <li>- Rise in sea level relative to land</li> </ul>
Coastal erosion and accretion	<ul style="list-style-type: none"> <li>- Length of protected and defended coastline</li> <li>- Length of dynamic coastline</li> <li>- Area and volume of sand nourishment</li> </ul>
Natural, human and economic assets at risk	<ul style="list-style-type: none"> <li>- Number of people living within an 'at risk' zone</li> <li>- Area of protected sites within an 'at risk' zone</li> </ul>

Source: Deduce Consortium (2007)

## **1.4 Aims and Objectives of the Project**

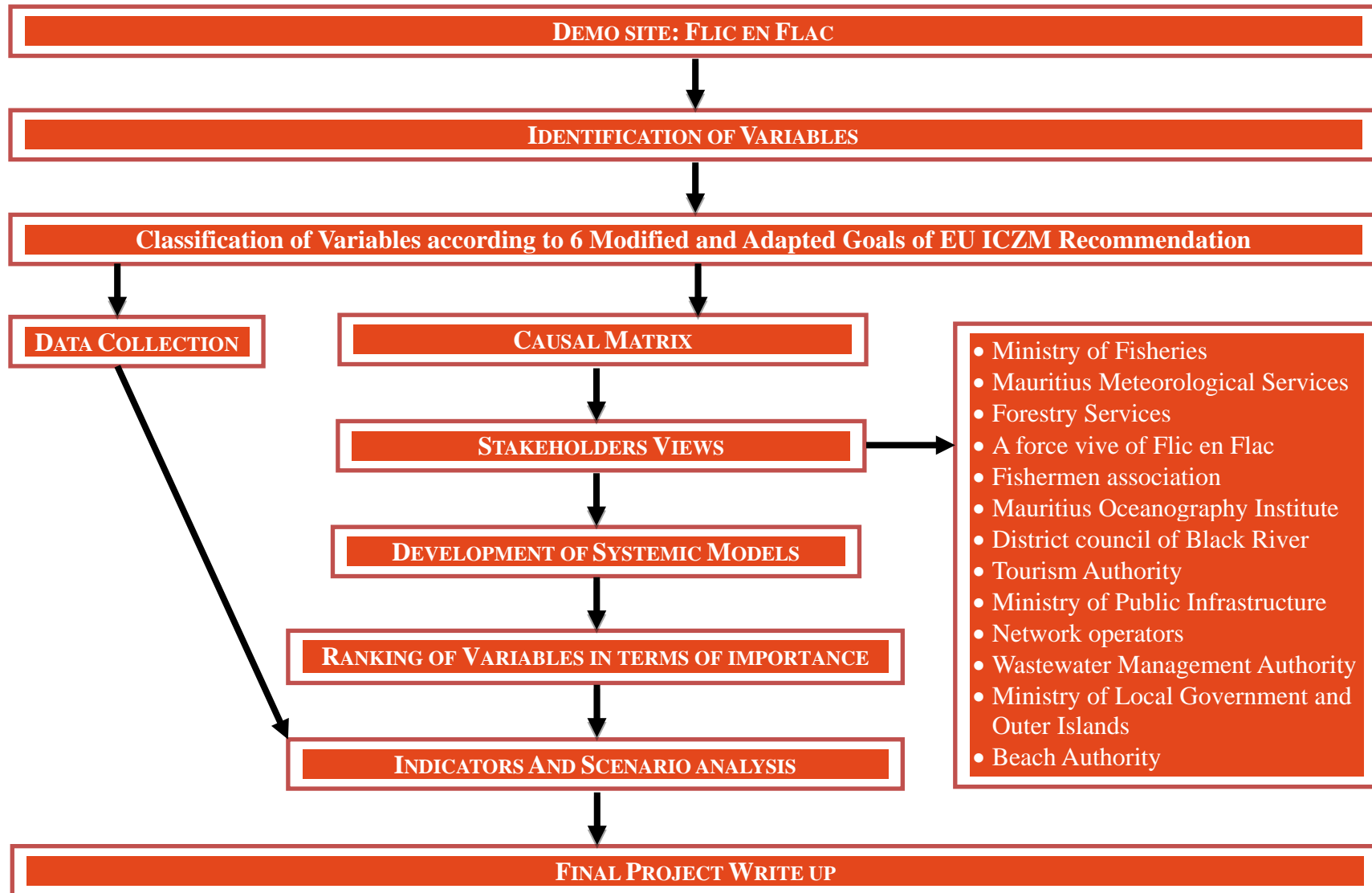
### **Aims**

The goal of integrated coastal zone planning and management consists of laying emphasis on the proper use of the numerous existing opportunities that coastal zones offer. Integrated coastal zone planning and management is of great importance to the coastal zones of Mauritius as these host numerous activities important to the economy. The project work will aim at finding out appropriate variables related to ICZM prevailing in Flic en Flac demo site. The use of System dynamics through Causal Loop Diagrams (CLDs) will help in identifying relationship between the variables and hence relevant indicators to the demo site.

The objectives of the project are:

- i. To have a clear picture of the coastal zone and the issues arising,
- ii. To find out whether a systems approach may be used to address coastal zone issues,
- iii. To develop a performance based model to identify a set of indicators which best describes the coastal zone to be used for evaluation and monitoring of ICZM,
- iv. To carry out scenario planning for specific demo sites using the model.

## 2.0 Methodology





## **2.1 Demo site: Flic en Flac**

The demo site under investigation is Flic en Flac coastal zone. Flic en Flac is a public proclaimed beach of an extent of 16.967 hectares (Beach Authority, 2012) located on the western coast of Mauritius in the Black River district. For the purpose of this project, Flic en Flac was chosen as demo site because it is a well-known public beach to Mauritians as well as tourists. Furthermore, Flic en Flac coastal zone has known rapid development in terms of construction for the touristic industry through the construction of five star, multi-national hotels, apartments and related amenities. Flic en Flac is also the residence of many Mauritians. Hence, the village is considered as an important touristic area. Moreover, Flic en Flac has known a rapid expansion in terms of its residential area with the construction of many houses as well as apartments.

## **2.2 Identification of Variables**

The coastal zone was delineated as per the Beach Authority which has proclaimed Flic en Flac as three public beaches: Flic en Flac/Wolmar (Near Pearl Beach Hotel), Flic en Flac (Near Manisa Hotel) and Flic en Flac (Opposite Restaurant Ocean). The next step was the identification of a series of variables within the delineation, based on the coastal zone issues: natural phenomena and human-induced conditions important to the Flic en Flac site.

## **2.3 Classification of Variables**

The EU ICZM Recommendation has been adapted to the Flic en Flac demo site: six goals have been retained and modified. Consequently, the variables were then classified according to the modified and adapted EU ICZM Recommendation.

## **2.4 Data Collection and Causal Matrix**

Data based on the identified coastal zone issues were sought from relevant institutions. However, not all data were obtained. A causal matrix consisting of the variables was designed and this survey was distributed among 13 stakeholders namely:

- i. Ministry of Fisheries
- ii. Mauritius Meteorological Services
- iii. Forestry Services
- iv. A force vive of Flic en Flac
- v. Fishermen association
- vi. Mauritius Oceanography Institute

- vii. District council of Black River
- viii. Tourism Authority
- ix. Ministry of Public Infrastructure
- x. Network operators
- xi. Wastewater management authority
- xii. Ministry of Local Government and Outer Islands
- xiii. Beach Authority

The survey aimed at determining whether any relationship exists between the variables: positive (+) or negative (-).

## 2.5 Development of Systemic Models

The stakeholders' views were the basis for the generation of Causal Loop Diagrams (CLDs). CLDs are used to illustrate the existing relationships between the variables in terms of positive (+) or negative (-). The CLDs were drawn using the VENSIM software by Ventana Systems, Inc.

## 2.6 Ranking of Variables in Terms of Importance

Based on the views of stakeholders, the variables were ranked in terms of importance. The ranking was done using the following formula:

$$R_i = (I_{VH} + I_{VV}) \times N_{out} \quad (Adapted\ from\ San\grave{o},\ 2009)$$

Where:

$R_i$  is the ranking in terms of importance

$I_{VH}$  and  $I_{VV}$  are the sum of importance of the coastal zone issues

$N_{out}$  is the number of outgoing arrows per issue

## 2.7 Identification of Indicators and Scenario Analysis

Based on the prevailing variables in the demo site, indicators have been identified. These indicators correspond to the variables and to the modified and adapted goals. Scenario analysis of the indicators based on three scenarios has been carried out. Scenario analysis will aid in identifying trends of the demo site and the implications if the simulation is forecasted on low, medium or high probabilities.

### 3.0 Results

#### 3.1 Variables identified for Flic en Flac demo site

Twenty variables identified based on the prevailing coastal zone issues in the demo site has been shown in the table below. The variables have been classified according to six goals of the EU ICZM Recommendation.

Table 3: Goals and Variables Specific to Flic en Flac Demo Site

FLIC EN FLAC DEMO SITE GOALS AND VARIABLES	
<b>1. Goal: To control further development of the undeveloped Flic en Flac coastal zone.</b>	1. Hotels and bungalows development
	2. Damage by speed boats and divers
	3. Number of inhabitants in Flic en Flac
<b>2. Goal: To protect, enhance and celebrate natural and cultural diversity.</b>	4. Protection of plants within the coastal zone of Flic en Flac
	5. Decrease in coral cover
<b>3. Goal: To promote and support a dynamic and sustainable coastal economy.</b>	6. Recreational activities for tourists
	7. Construction of roads
	8. Installation of communication services
	9. Leisure/recreational activities for residents of Flic en Flac and Mauritians
<b>4. Goal: To ensure that beaches of Flic en Flac are clean and that coastal waters are unpolluted.</b>	10. Sea water quality
	11. Quality of sand on the beach
	12. Discharge of wastewater
	13. Cleaning and scavenging services on the beach of Flic en Flac
	14. Available facilities on the beach to the public
<b>5. Goal: To use natural resources wisely.</b>	15. Maintenance of Flic en Flac beach
	16. Degraded marine ecosystem
<b>6. Goal: To recognize the threat to coastal zones posed by climate change and to ensure appropriate and ecologically responsible coastal protection.</b>	17. Exploitation of marine resources
	18. Widespread coastal erosion
	19. Climate change effects and extreme climatic conditions
	20. Flooding

### 3.2 Data Collection and Presentation

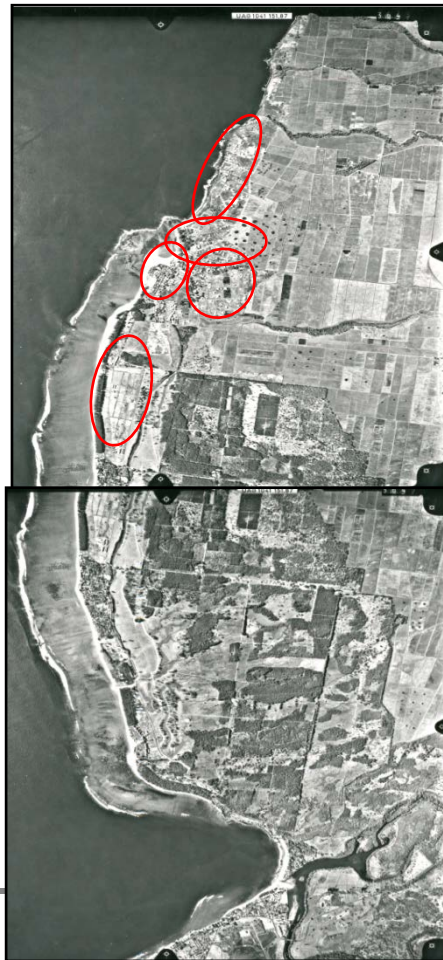
Based on the twenty ICZM related variables specific to Flic en Flac demo site, data from relevant institutions and stakeholders have been collected. These data are classified according to the six goals.

#### 3.2.1 Evolution of Development in Flic en Flac

The maps below show an evolution of the development in terms of building from the year 1967, 1991 to 2008. The red ovals illustrate areas whereby there have been constructions of buildings.



1967



1991



2008



### 3.2.2 Goal: To control further development of the undeveloped Flic en Flac coastal zone.

#### Hotels and bungalows development

##### List of registered hotels in Flic en Flac

A list of registered hotels as at 31 March 2012 has been obtained from the CSO. The type of hotel, i.e. the hotel's location, the number of rooms and bed places are shown in the table below. As at 31 March 2012, in the demo site in the district of Black river, there were 14 hotels all of which are found on the beach of Flic en Flac.

**Table 4: List of Registered Hotels in Flic en Flac**

	<b>LIST OF HOTEL IN FLIC EN FLAC</b>	<b>TYPE</b>	<b>ROOMS</b>	<b>BED PLACES</b>
1.	Aanari Hotel & Spa	Beach	50	100
2.	Gold Beach Resort (Ex Villas Sand N Dory)	Beach	31	80
3.	Hilton Mauritius Resort & Spa	Beach	193	386
4.	Klondike Village Vacances	Beach	31	90
5.	La Pirogue Hotel & Casino	Beach	248	496
6.	Le Pearle Beach	Beach	74	148
7.	Manisa Hotel	Beach	54	108
8.	Maradiva Villas Resort & Spa (Ex Taj Exotica Resort & Spa Mauritius)	Beach	65	130
9.	Palm Tree Garden Hotel	Beach	24	50
10.	Sofitel Imperial Hotel	Beach	191	357
11.	Sugar Beach Resort	Beach	258	516
12.	The Sands Resort	Beach	92	184
13.	Villa Paul et Virginie Casa Pizza	Beach	12	24
14.	Villas Caroline	Beach	75	150

## Type of building

The CSO census of 2000 and 2011 has records of the following types of building in Flic en Flac:

1. Building under construction and not inhabited
2. Block of flats containing three or more housing units
3. Tourist residence
4. Hotel
5. Institutions such as convent, infirmary, hospital, barracks
6. Public building
7. Commercial building
8. Other non-residential building

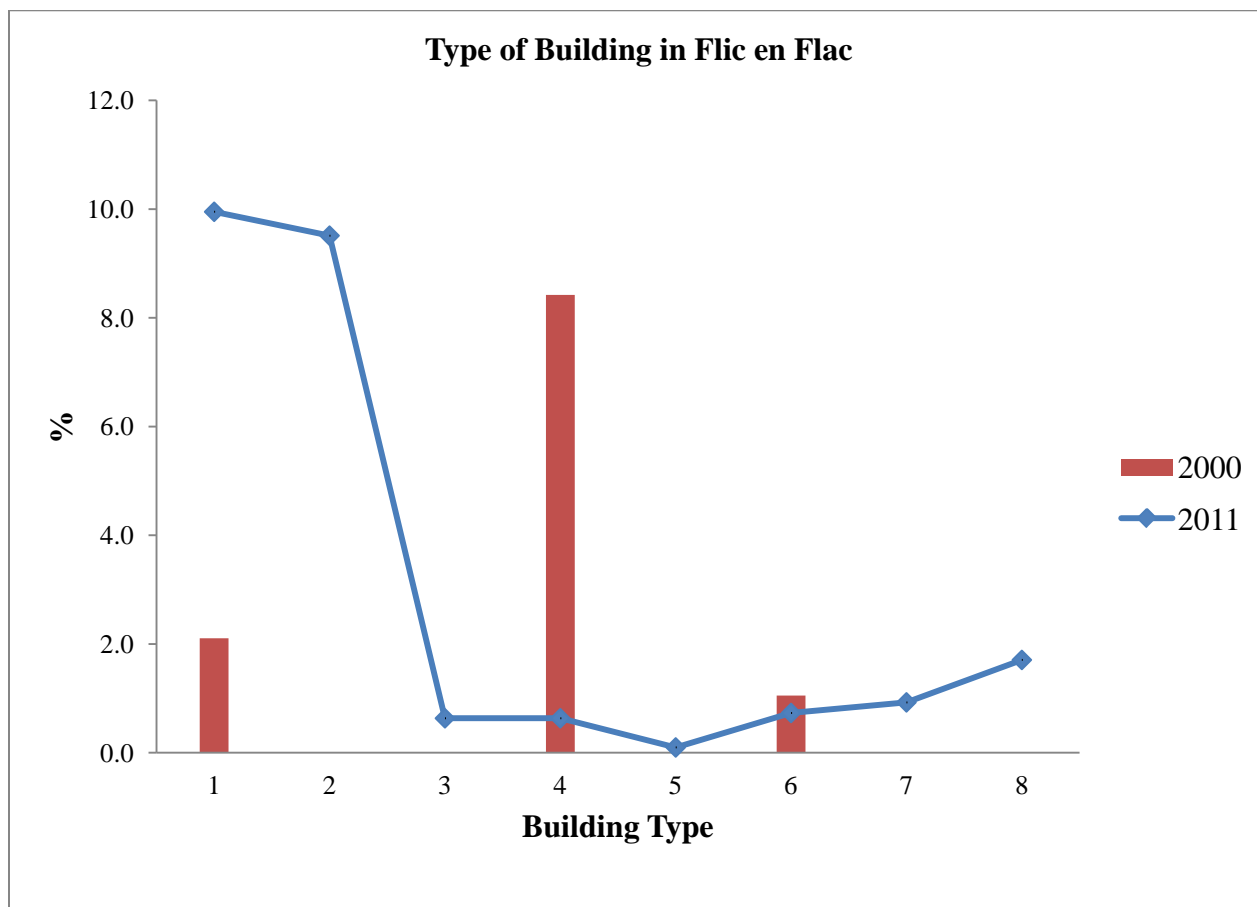
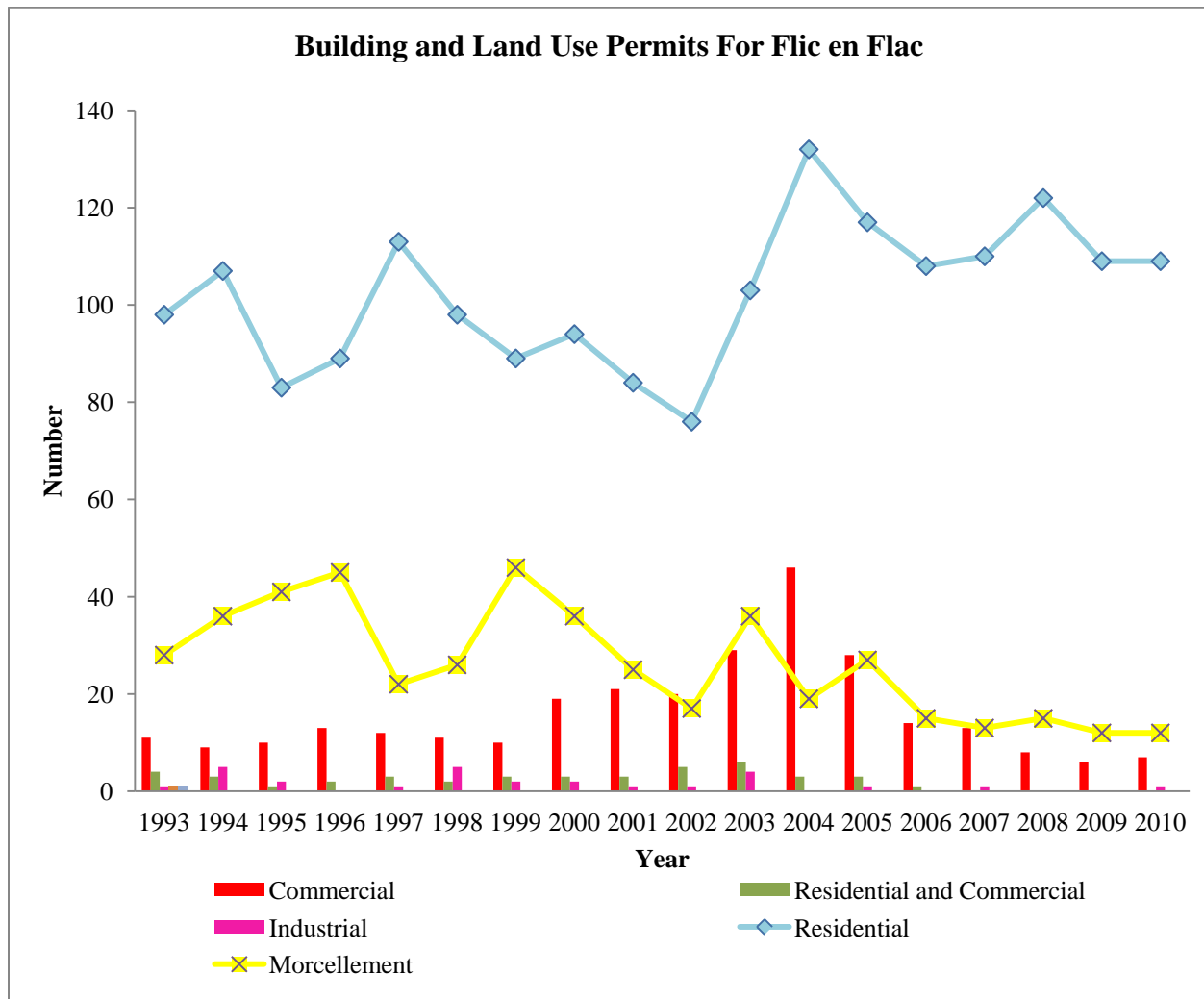


Figure 2: Chart illustrating the type of building for the years 2000 and 2011

## Building and Land Use Permits

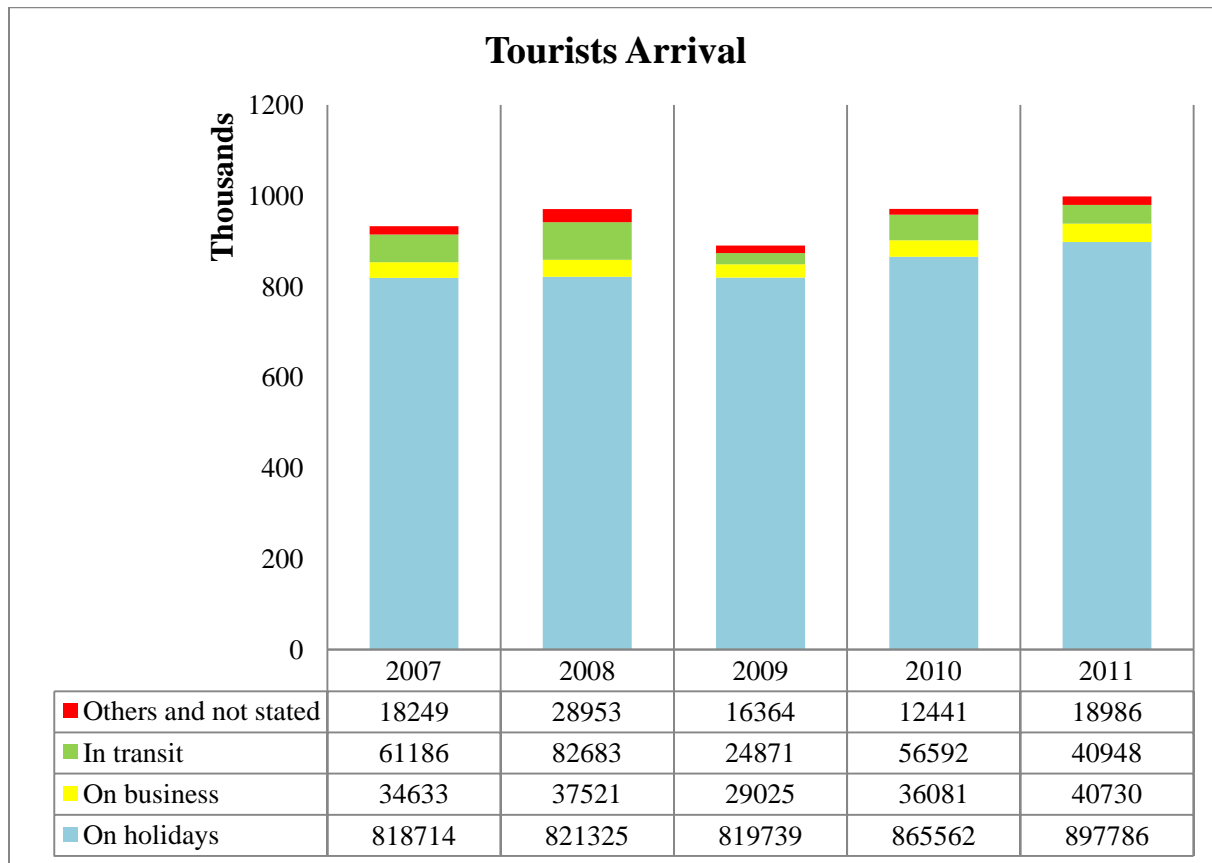
The District council of Black River has records of building types from the year 1993 up to 2010 which is illustrated in the chart below.



**Figure 3: Permits for Building and Land Use in Flic en Flac**

## Tourist Arrival

The number of tourists visiting Mauritius from the year 2007 to the year 2011 for different purposes is illustrated.

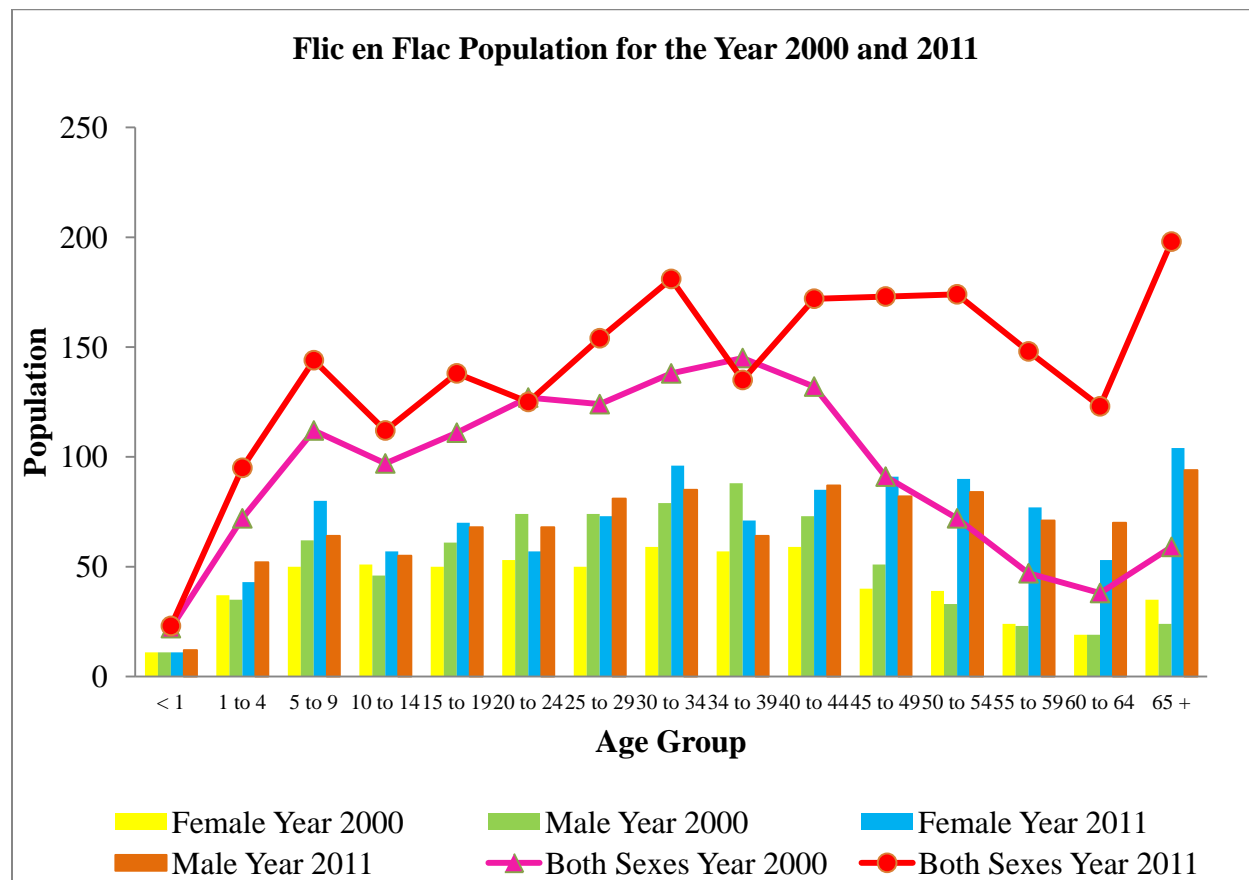


**Figure 4: Tourists Arrival (in thousands) in Mauritius**



## Population of Flic en Flac

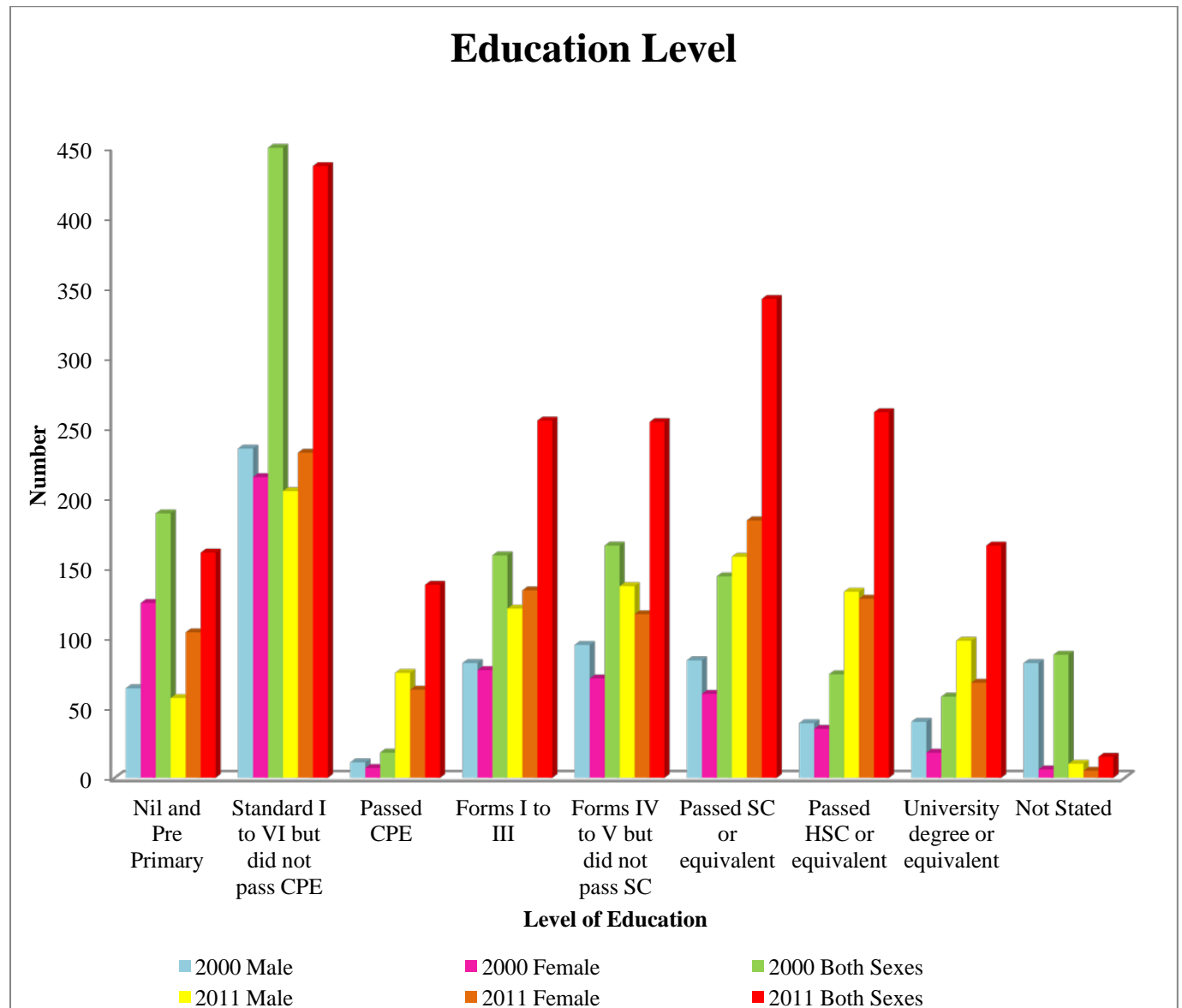
Based on the two censuses carried out by CSO the year 2000 and 2011, the male, female and both sexes population have been illustrated in the chart below.



**Figure 5: Population of Flic en Flac for the year 2000 and 2011**

## Level of Education

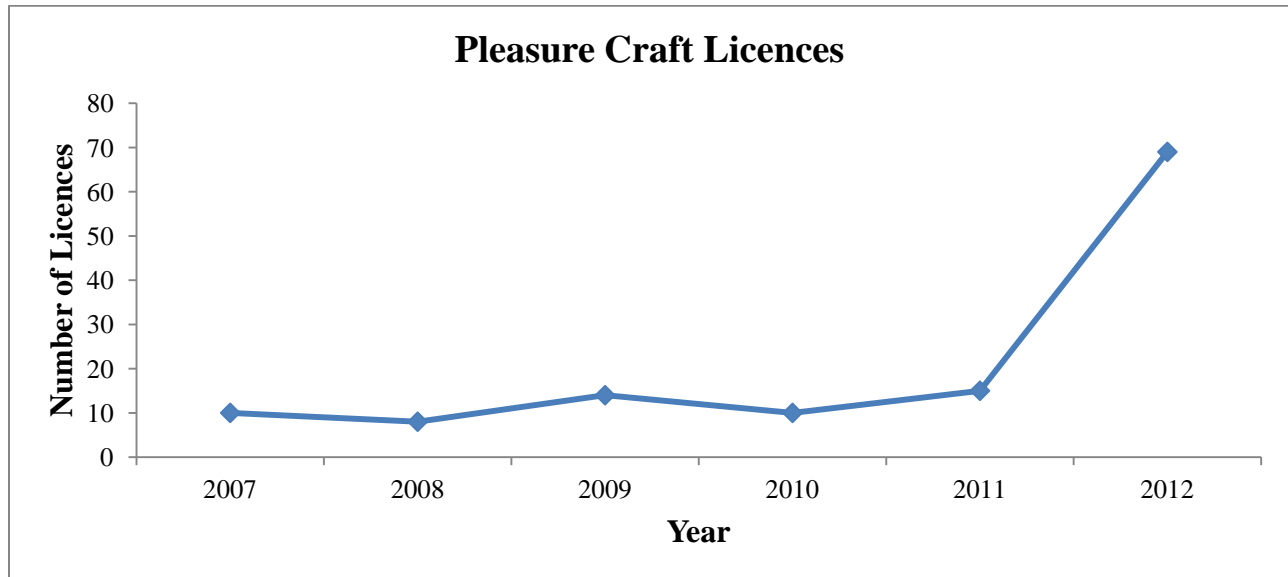
Inhabitants of Flic en Flac have attained different levels of education as per the 2000 and 2011 census carried out.



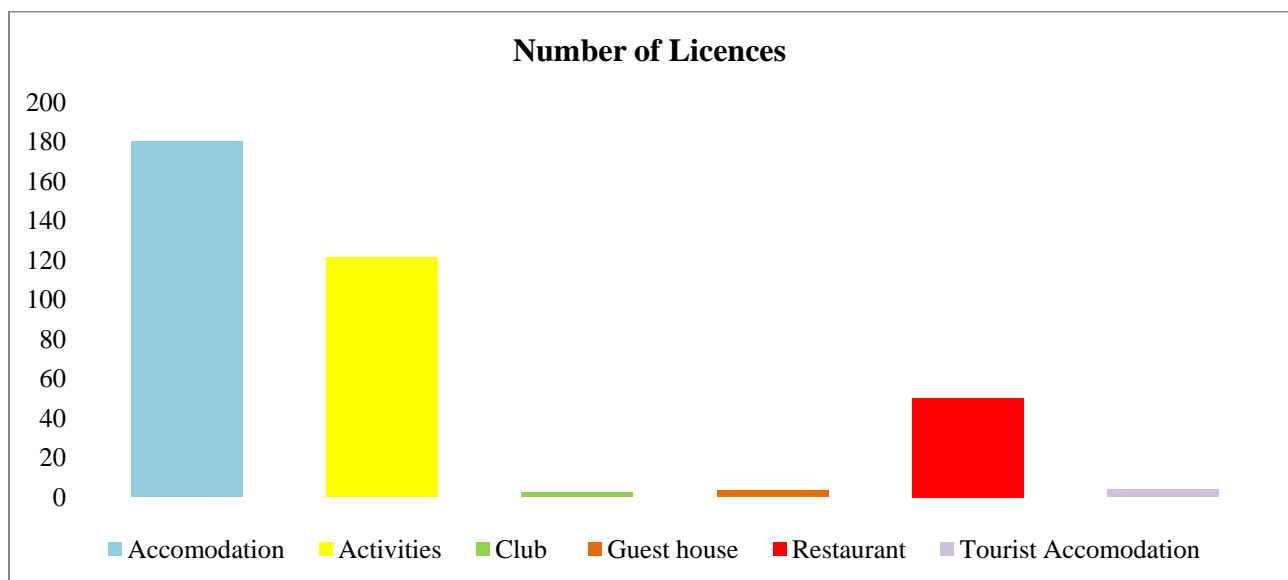
### 3.2.3 Goal: To promote and support a dynamic and sustainable coastal economy.

#### Recreational activities for tourists

The number of pleasure craft licences from the year 2007 to 2012 is illustrated in the graph below.

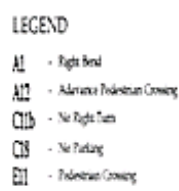


The number of licences in terms of accomodation, activities, club, guest house, restaurant and tourist accomodation as at June 2012 is shown in the bar chart below.



The map below shows the coastal road of Flic en Flac as at 2012.

The map below shows the coastal road of Flic en Flac as at 2012.



Installation of communication services

The three network operators have installed base stations in the region of Flic en Flac as shown in the map:



<div><div></div><div></div></div>	Emtel
<div><div></div><div></div></div>	Orange
<div><div></div></div>	MTML

Figure 6: Map illustrating base stations of Emtel, orange and MTML

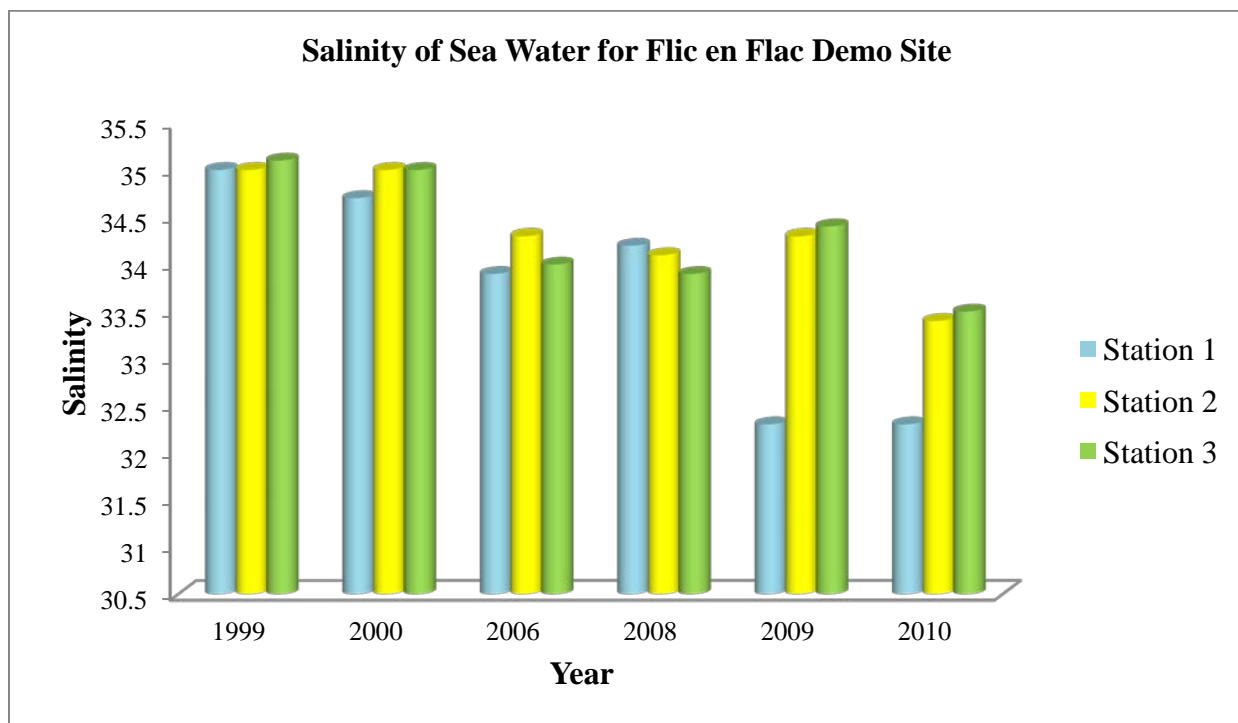
**3.2.4 Goal: To ensure that beaches of Flic en Flac are clean and that coastal waters are unpolluted.**

### **Sea water quality**

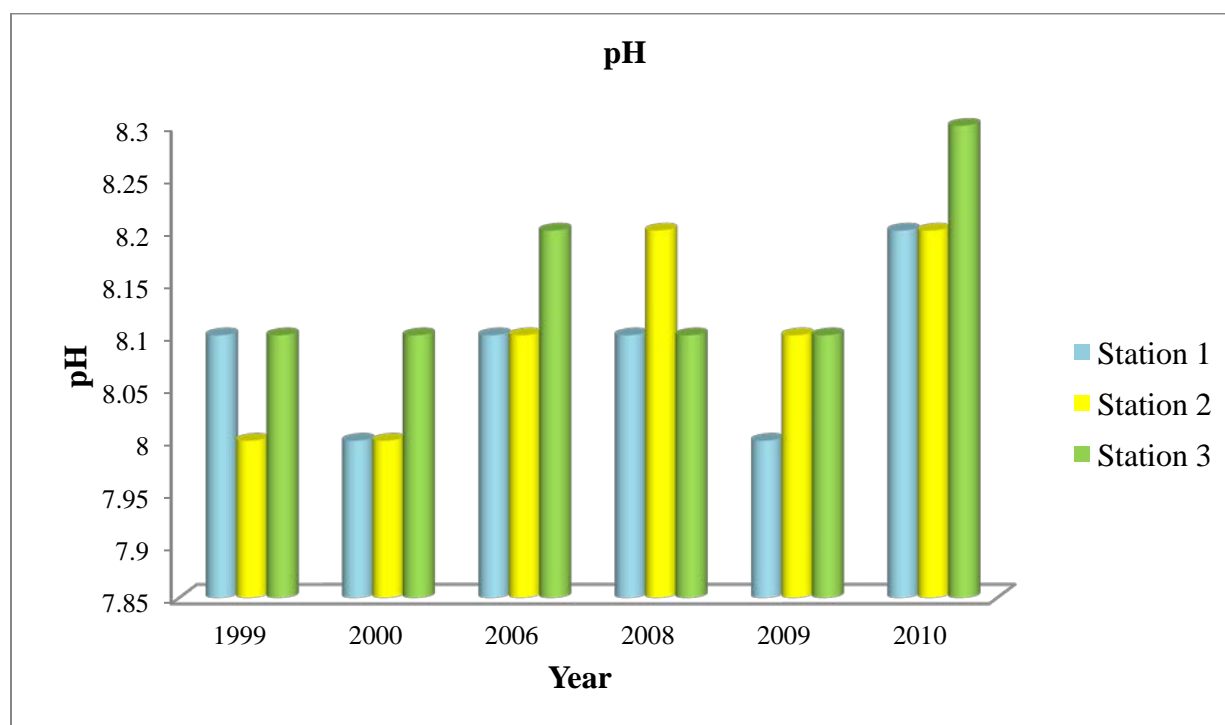
Physico-chemical data for the analysis of the sea water of Flic en Flac demo site has been obtained for the year 1999 to 2010 from the Ministry of Fisheries. Within the demo site, the Ministry of Fisheries has three monitoring stations:

- Station 1 is the fish landing station opposite Ocean Restaurant
- Station 2 is opposite La Pirogue/Pearl Beach
- Station 3 is Manisa Hotel/Limekiln

The physico-chemical parameters: salinity, pH, Dissolved Oxygen, Chemical Oxygen Demand, Nitrate-Nitrogen Level and Phosphate level as monitored by the Ministry of Fisheries are illustrated below.



**Figure 7: Salinity of Flic en Flac Sea Water**



**Figure 8: pH of seawater of Flic en Flac**

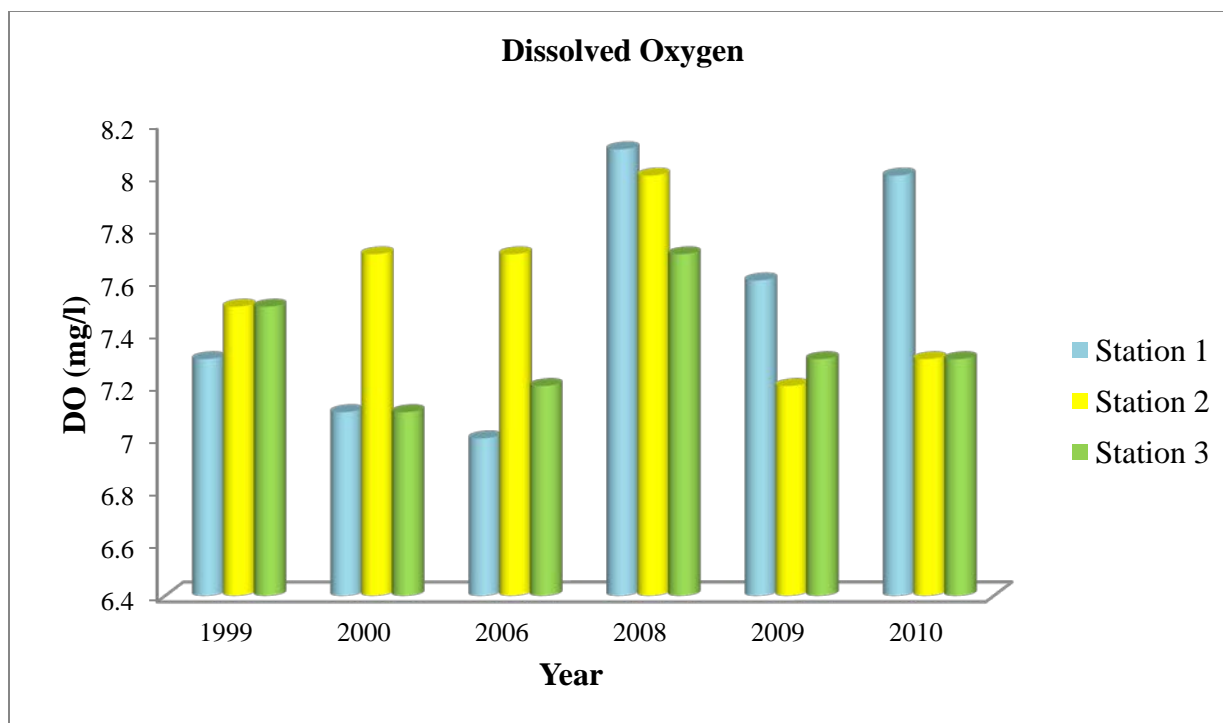


Figure 9: Yearly average DO for Flic en Flac Sea water

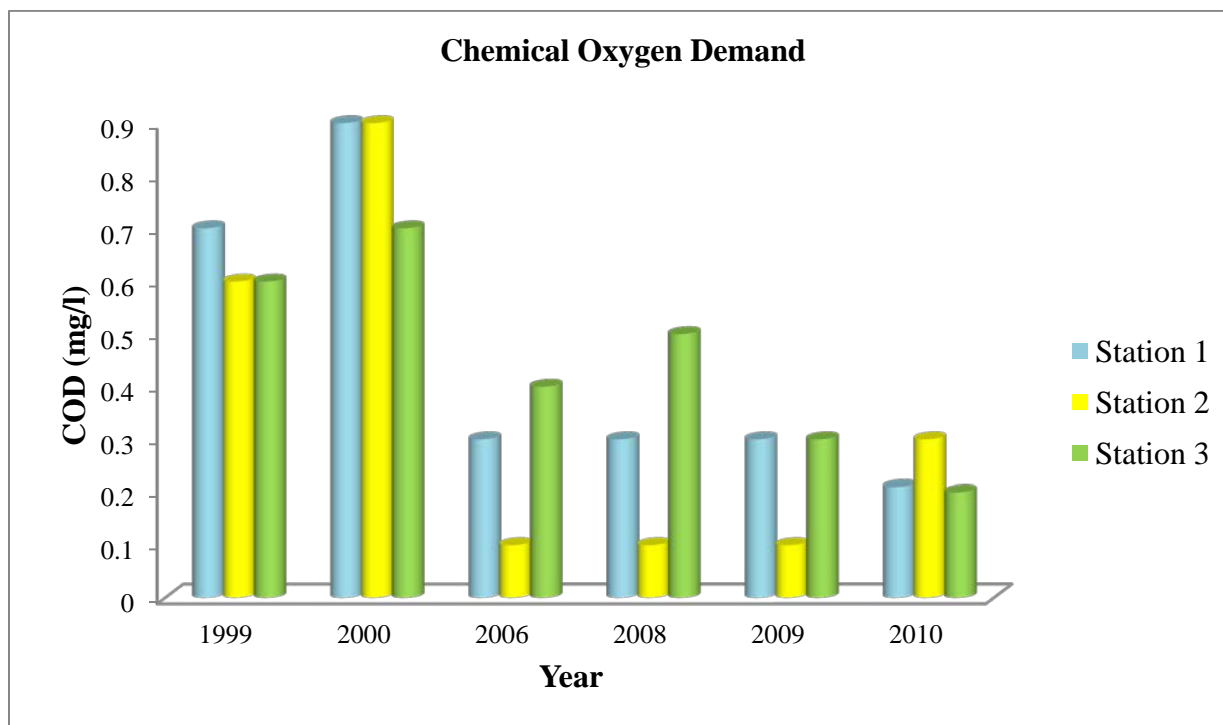
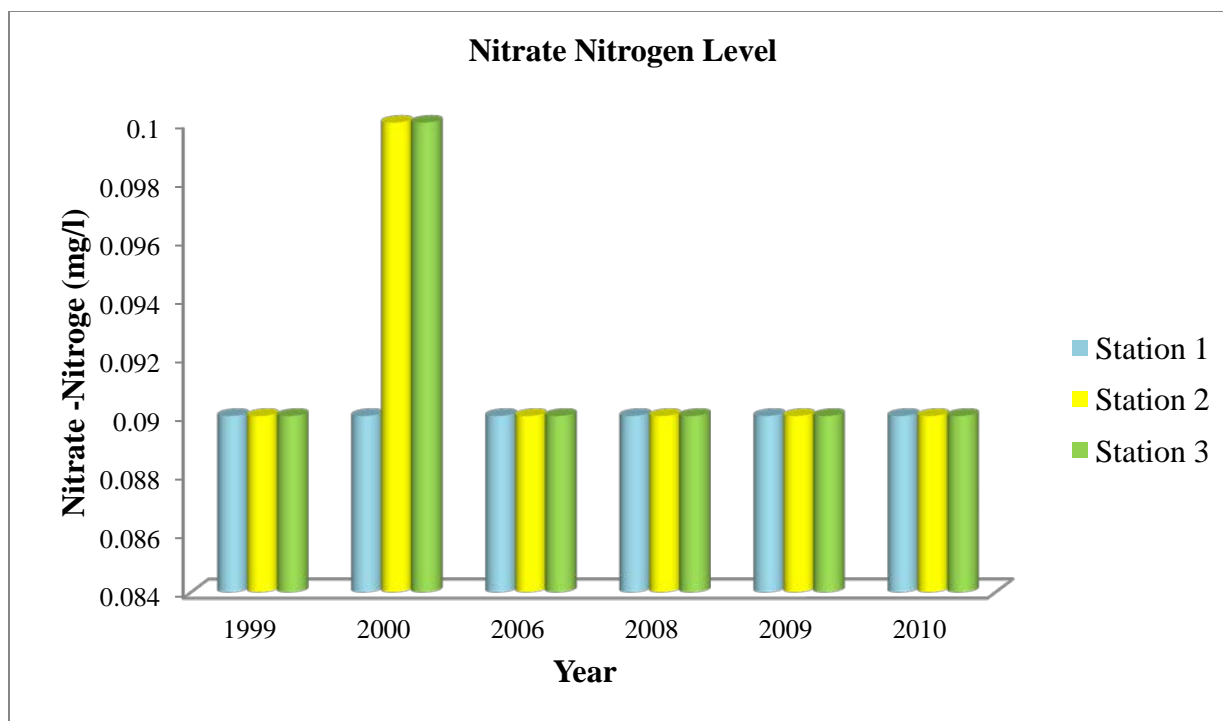
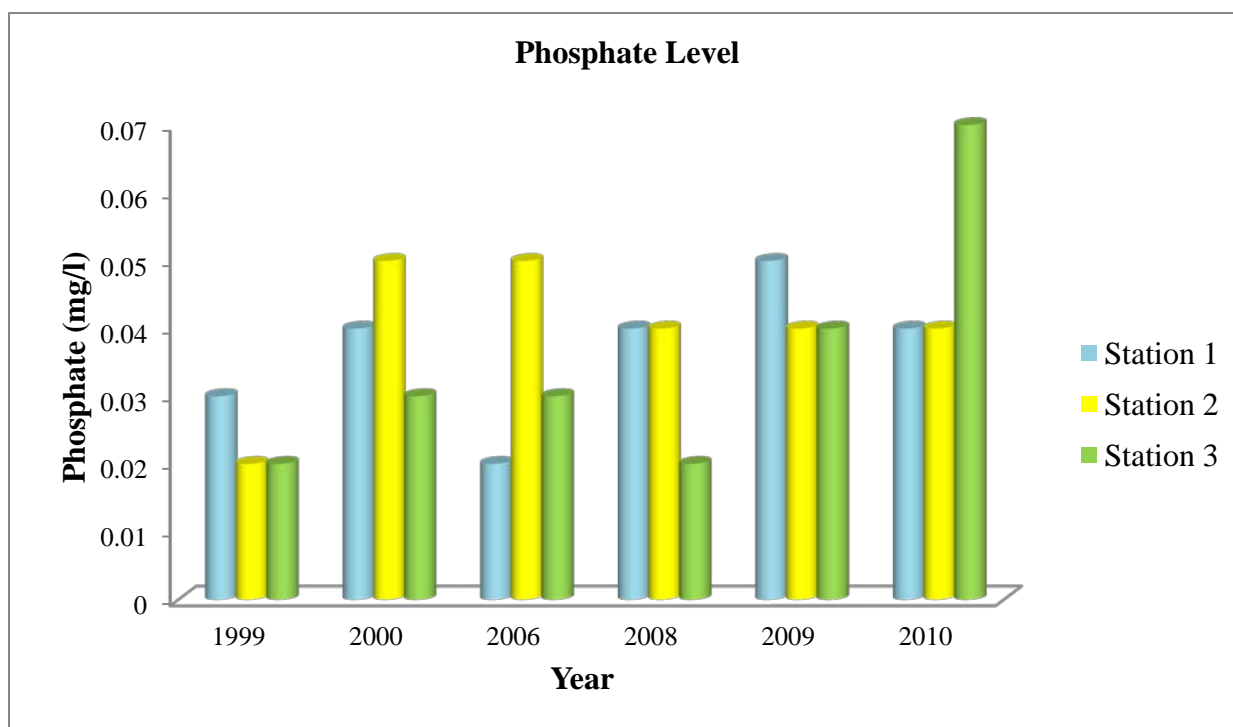


Figure 10: COD measurements on a yearly basis for Flic en Flac sea water





**Figure 11: Nitrate Nitrogen Level for sea water in Flic en Flac**



**Figure 12: Level of Phosphate for Flic en Flac**

The charts above show the average values for the years 1999, 2000, 2006, 2008, 2009 and 2010. Data only for the years 1999, 2000, 2006, 2008, 2009 and 2010 have been obtained from the Ministry as Flic en Flac was not considered as a regular monitoring site for the years 2001 to 2005 and 2007.

The pH, DO, COD, Nitrate and Phosphate levels for the years 1999, 2000, 2006, 2008, 2009 and 2010 are within the Coastal water Quality Guidelines (CWQG) under the recreation category. The acceptable ranges are shown below:

**Table 5: Acceptable CWQG for recreation purposes**

Parameters	CWQG
pH	7.5 – 8.5
DO (mg/l)	>5
COD (mg/l)	3.0
NO <sub>3</sub> – N (mg/l)	0.8
PO <sub>4</sub> <sup>3-</sup> (mg/l)	0.08

### Faecal and Total Coliforms monitoring

Samples of water are collected from three stations and are analysed for Total Coliform and Faecal Coliform. The three monitoring stations for Flic en Flac are:

- Station 1: opposite Ocean Restaurant
- Station 2: Beside Pearl Beach Hotel
- Station 3: Opposite old limekiln

The obtained data from the Ministry of Fisheries shows the average bacteriological data from the year 1997 to 2010. All obtained parameters are within the CWQG which stipulates that:

- Total Coliform (TC) should be less than 1000 CFU/100ml and
- Faecal Coliform (FC) should be less than 200 CFU/100ml.

*CFU stands for Colony Forming Unit.*

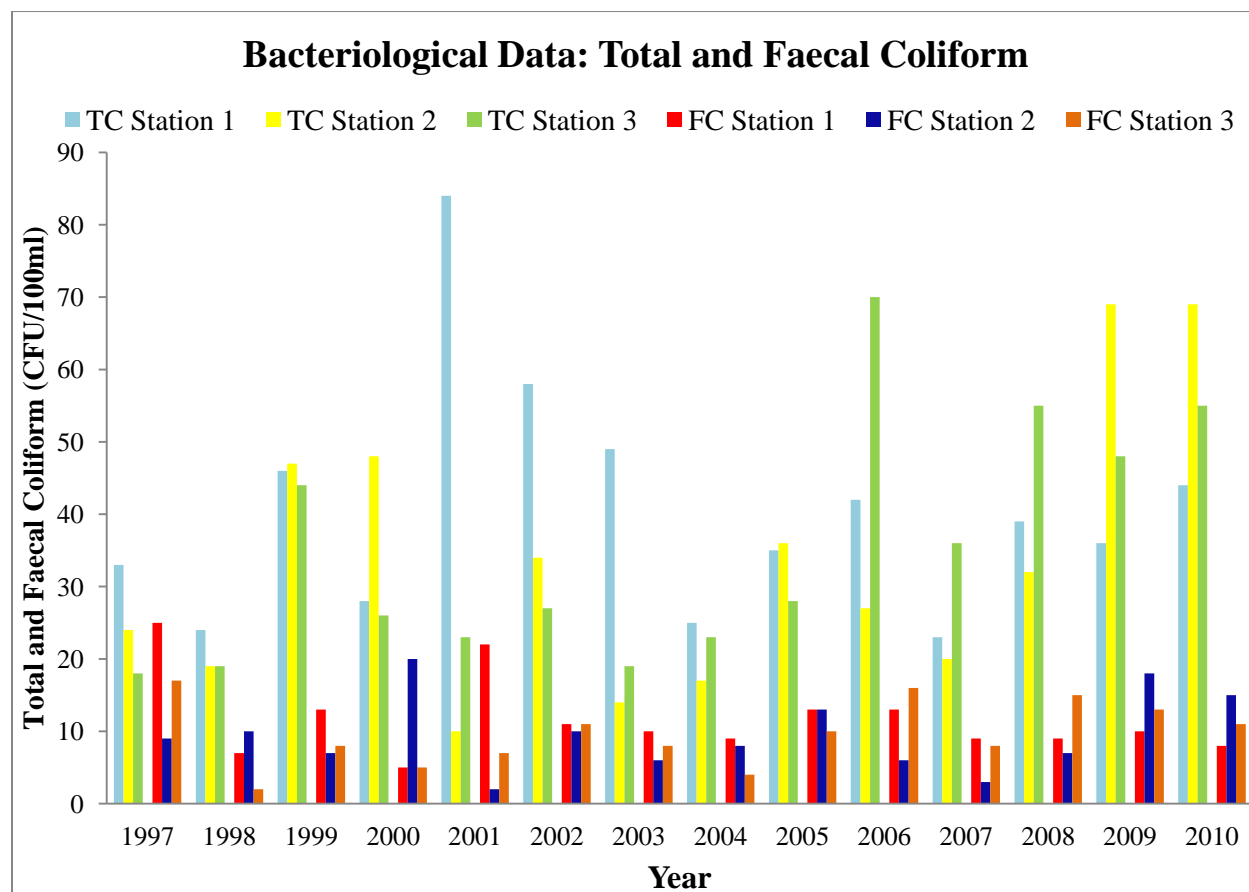
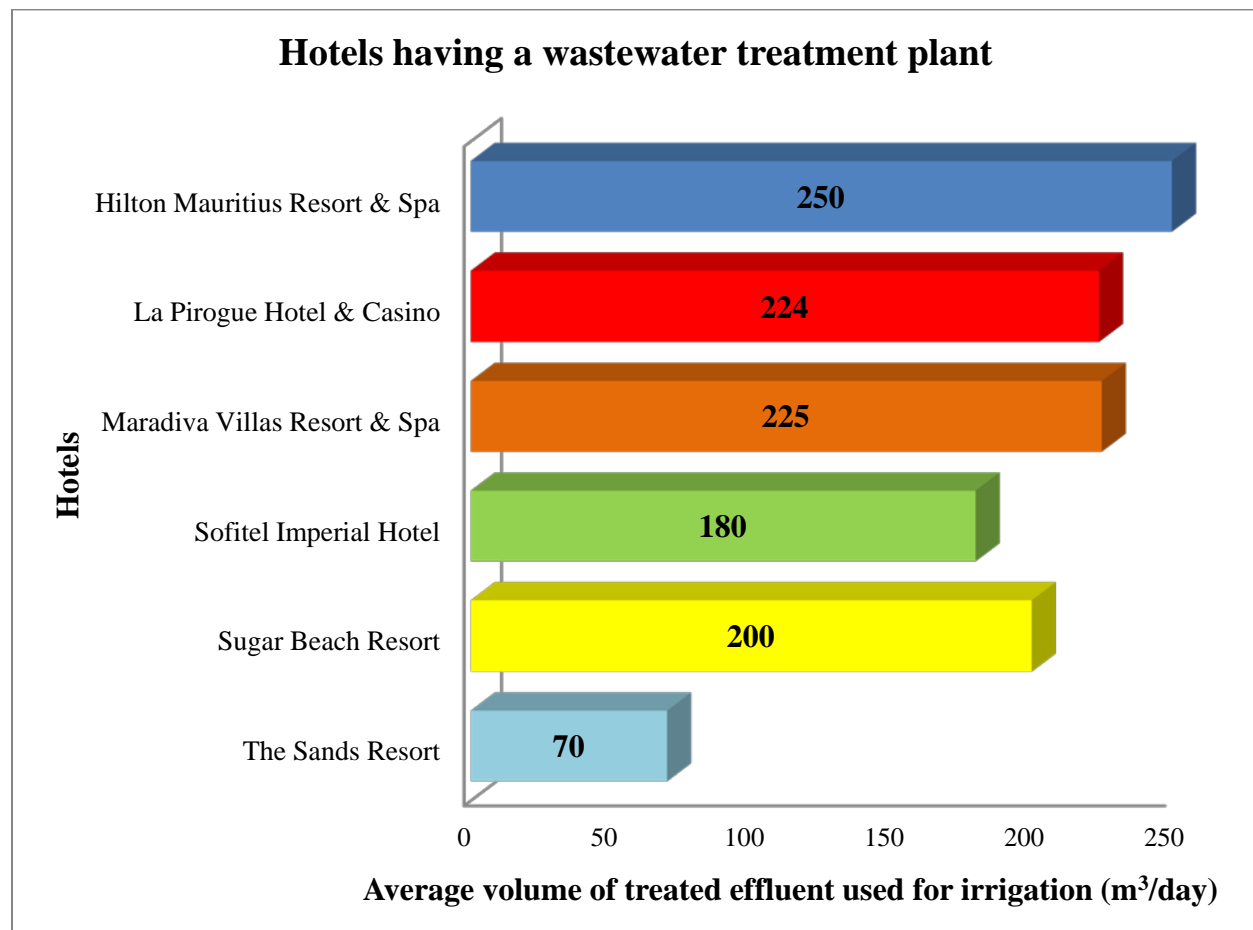


Figure 13: Total and Faecal Coliform Analysis for Flic en Flac for the year 1997 to 2010

### Discharge of wastewater

The Wastewater Management Authority (WMA) records the amount of effluent that is treated by hotels and which is in turn used for irrigation. As per WMA, only 6 hotels in Flic en Flac have an installed wastewater treatment plant.



**Figure 14: Average volume of treated effluent per day by hotels in Flic en Flac**

### Maintenance of Flic en Flac beach and Cleaning and scavenging services in Flic en Flac

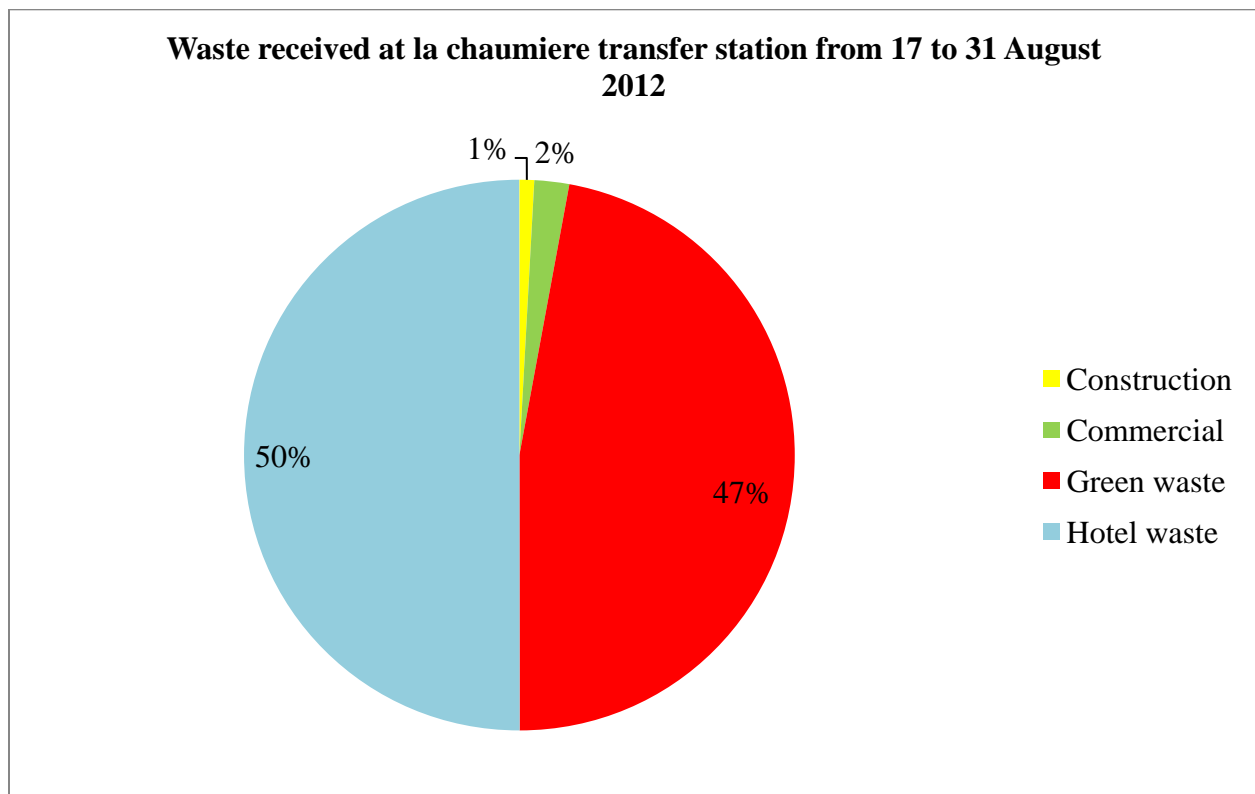
The cleaning of the beach is done on a daily basis. Scavenging services for the village of Flic en Flac provided by the District council of Black River is carried twice weekly. Rivers found in Flic en Flac are also cleaned two times per week. These services are contracted out to Securiclean and Mauritius Maxi Clean Company Limited companies. Waste collected within the region of Flic en Flac are then transported either to La Chaumière Compost Plant or to La Chaumière Transfer Station depending on the type of waste.

The table below shows the amount of green waste transferred to La Chaumière Compost Plant by the Securiclean Mauritius Limited from Flic en Flac for the months of September and August:

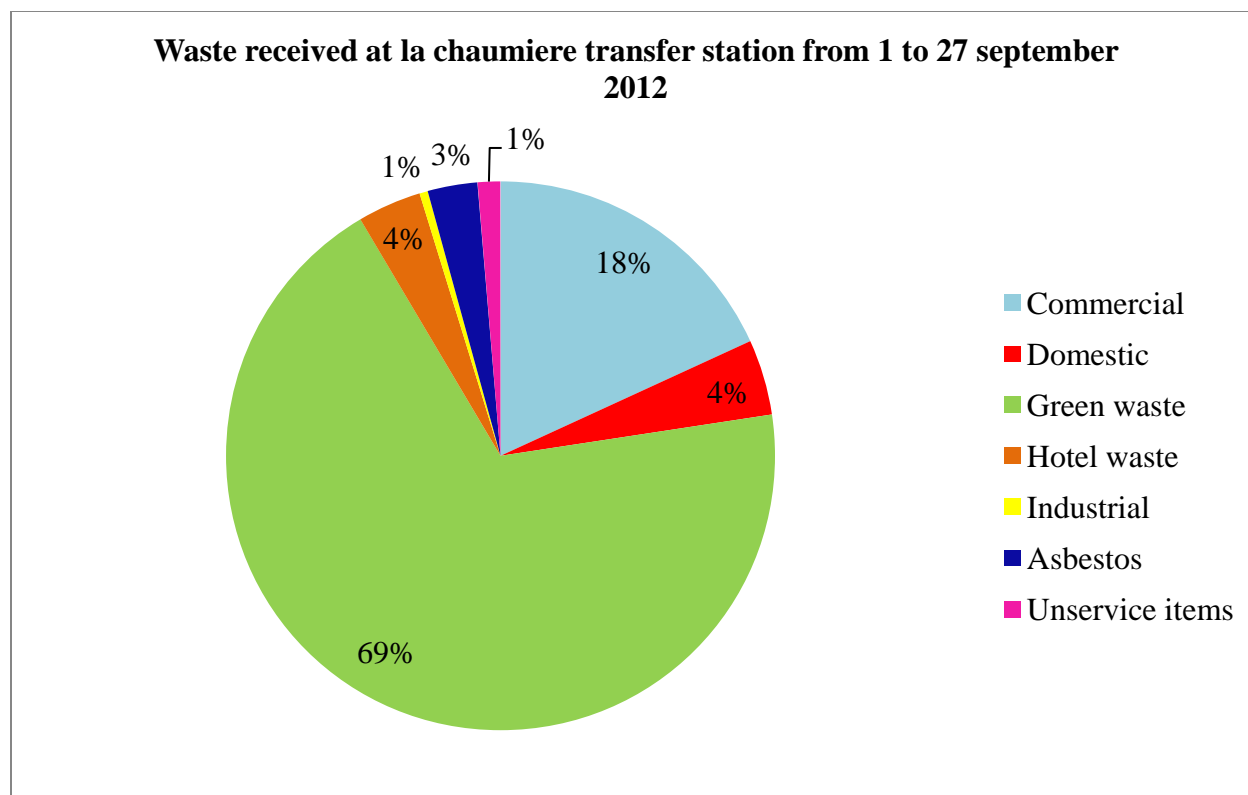
**Table 6: Amount of waste transferred to La Chaumière Compost Plant**

Date	Amount of Waste (kg)
1-23 September 2012	11,820
August 2012	26,050

Contractors or conveyors transport collected waste from Flic en Flac to La Chaumiere Transfer Station whereby a daily monitoring is carried out. The transfer station take records of the type of waste, the gross weight, net weight and tare of lorries' on a daily basis.



**Figure 15: Pie Chart illustrating the percentage of waste transported to La Chaumière Transfer Station for the month of August**



**Figure 16: Pie Chart illustrating the percentage of waste transported to La Chaumière Transfer Station for the month of September**

## Available facilities/amenities on the beaches of Flic en Flac

The Beach Authority is responsible for providing and maintaining facilities on the public beaches of Flic en Flac. The table below shows the amenities/facilities and the number present at Flic en Flac as at 23 October 2010.

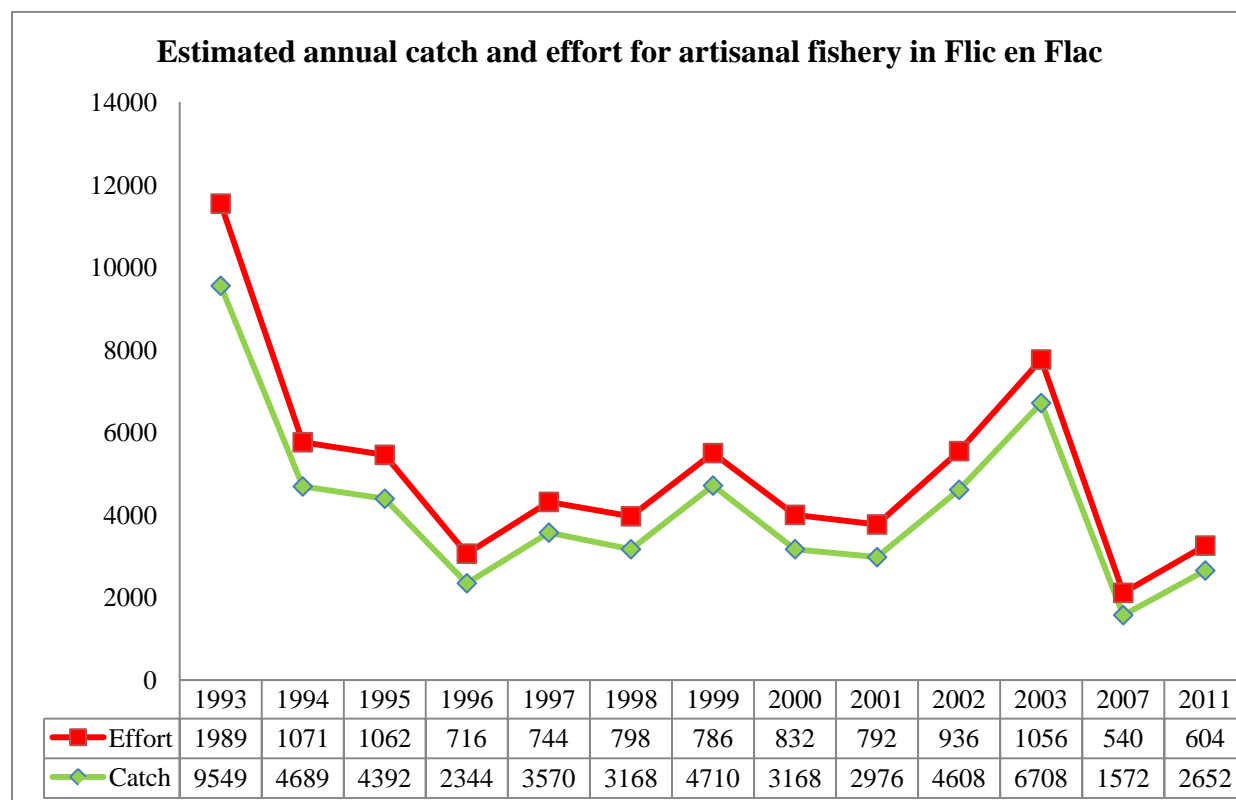
**Table 7: Amenities/Facilities in Flic en Flac demo site**

<b>Amenities/Facilities</b>		<b>Number</b>
<b>Fire Place</b>	Concrete	4
<b>Bins</b>	- Metal Bins	22
	- Main (Concrete)	3
	- Pivoting Drum	7
	- Metal with Iron sheet	2
	- Inox	
	- Profiling	
	- Other types	51
<b>Pinepoles</b>	For parking areas and beach traders zones	More than 100
<b>Toilet Block</b>	- Concrete building with a profilage sheet roof	2
<b>Mini Kiosk</b>	Made of concrete	4
<b>Lighting poles</b>	- Double arm lamp post	12
	- New ones	40
<b>Picnic Table</b>		1
<b>Dangerous Bathing Panel</b>	- Made of Concrete	1
	- Made of Metal	1
<b>Information Panel</b>		4
<b>Open shower</b>		1
<b>Concrete tuckshop</b>		3
<b>Concrete fire place</b>		2
<b>Benches</b>	- Concrete	4
	- Metal with wooden planks	5
	- Prefabricated benches	2

### 3.2.5 Goal: To use natural resources wisely.

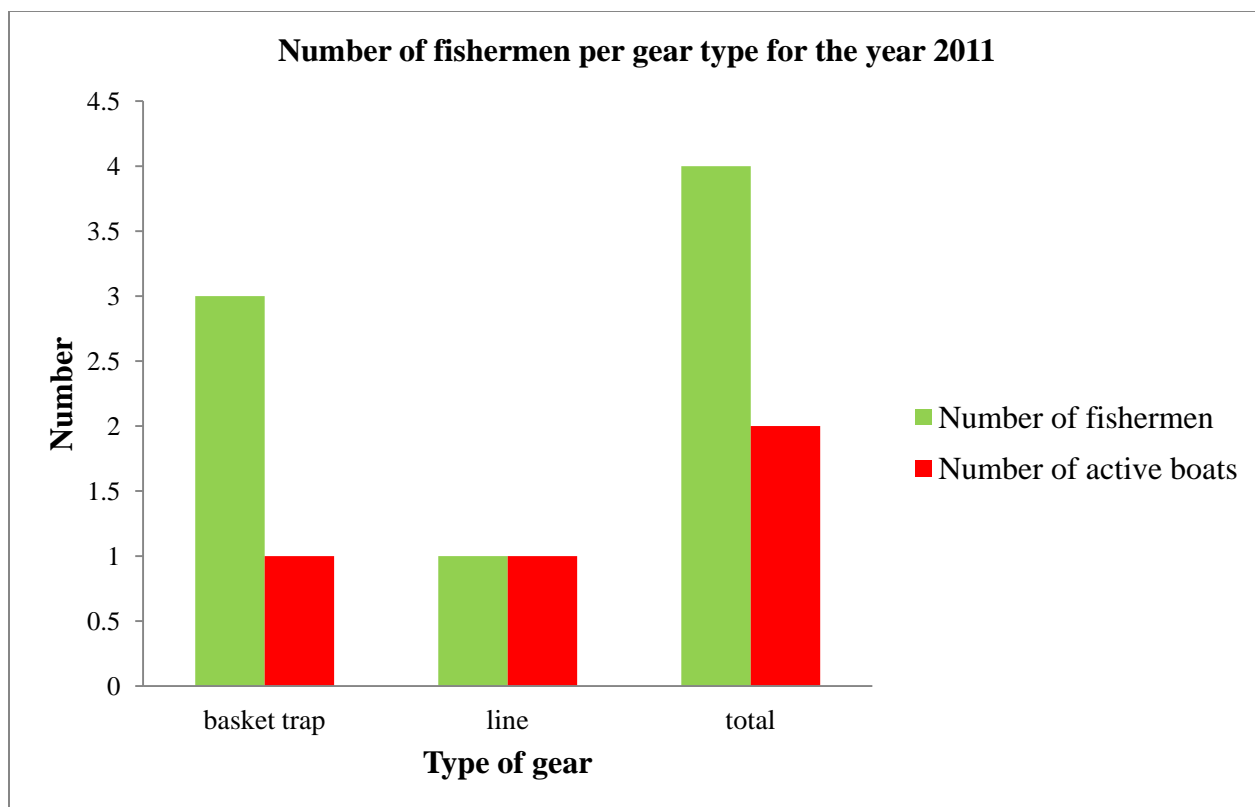
#### Exploitation of marine resources

Artisanal fishery is practiced in the region of Flic en Flac. The Ministry of Fisheries collects data on the annual catch and effort of fisherman. Data for the years 2004, 2005, 2006, 2009 to 2010 are not available as during those years no sampling has been carried out.



**Figure 17: Graph showing the estimated catch and effort for artisanal fishery from 1993 to 2003, 2007 and 2011**





**Figure 18: Number of fisher per type of gear for Flic en Flac**

### 3.3 Stakeholders Views

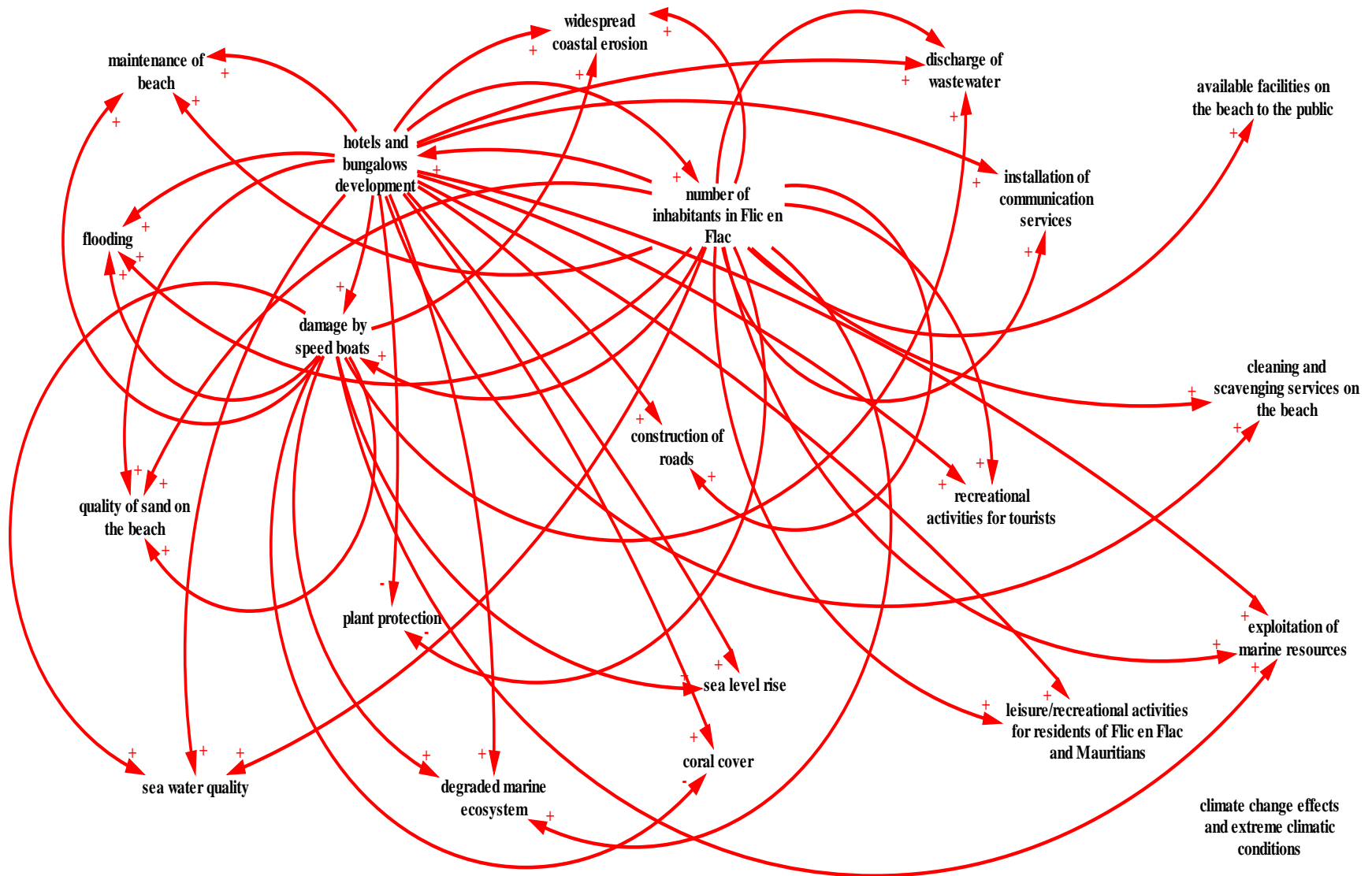
The views of the stakeholders have been compiled and presented below:

		GOAL 1			GOAL 2		GOAL 3			GOAL 4						GOAL 5		GOAL 6			
		V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17	V18	V19	V20
GOAL 1	V1			2+					2+												
	V2	13+		13+			13+		13+	13+					11+	13+					
	V3	13+			13+			13+	13+					13+	4+	13+					
GOAL 2	V4	13-		13-		13-	13-	13-	13+	13-	13-	13-	13+	13-	13-	13-			13-	13-	13-
	V5	13+	13+	11+	11-		13+		13+	13+	2+	13+	11-		11+	13+	13+	13+	13+	13+	13+
GOAL 3	V6	13+		2+					2+						2+						
	V7	13+		13+																	
	V8	13+		13+				13+													
	V9	13+		13+									13+		13+						
GOAL 4	V10		13+	13+	11-	13+	13+	13+		13+		13+	13+	13-	13+	11+	13+	13+	13+	13+	13+
	V11	13+	13+	11+	11-		11+		11-	11+	13+		13+	11-	11-	11+	13+	11+	13+	13+	13+
	V12	13+		13+				13+					11+								
	V13	13+	13+	13+	13+	13+	13+		13+	13+	13+	13+	13+		13+	13+	13+	13+	13+	13+	13+
	V14	13+		13+			13+	13+		13+						13+					
	V15			13+					13+												
GOAL 5	V16	13+	13+	11+		13+	13+			13+	13+	13+	13+	2+	13-	11+		9+	13+	13+	11+
	V17	11+	13+	11+			13+			13+	13+		13+			13+	13+				
GOAL 6	V18	13+	4+	13+	11-	13+	13+				9+		9+	9+	13+	7+	4+	4+		13+	7+
	V19	4+	4+			7+	13+				4+	4+	4+				4+	4+			7+
	V20	11+	11+	11+		11+					11+	11+	11+	11-			11+	11+	13+	13+	13+

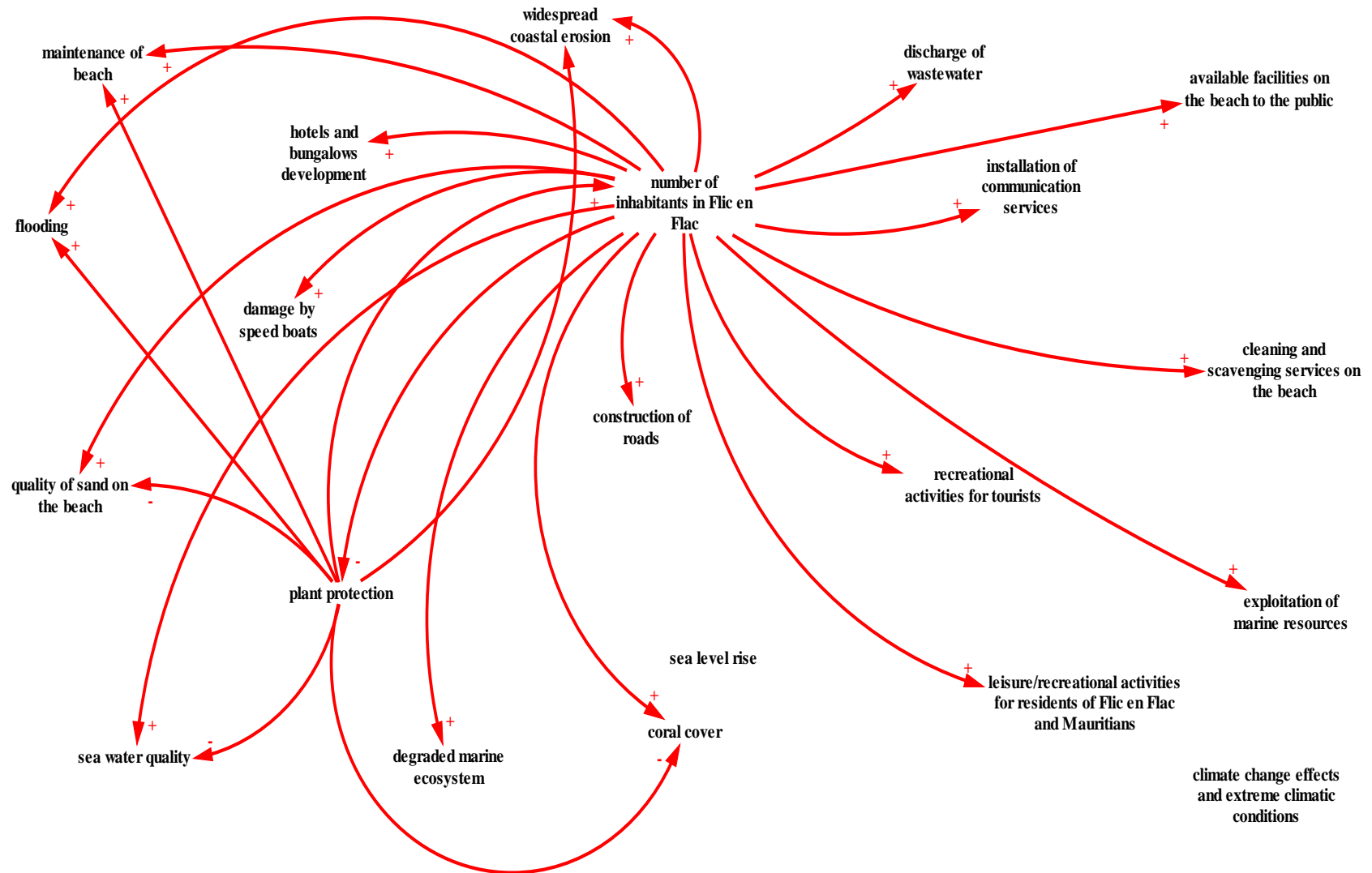
### **3.4 Systemic model based on survey**

Based on results obtained from the survey, a systemic model consists of Causal Loop Diagrams (CLDs). The CLDs help to view visually see the existing relationship(s) if any. These relationships are expressed in terms of plus (+) and negative (-) signs. The plus (+) sign indicates that the variable is the cause of an increase of another variable while the negative (-) sign suggests that the variable causes a decrease of the other one. The CLDs have been drawn based on the six goals, i.e. the interaction of the variables of one goal with the other variables.

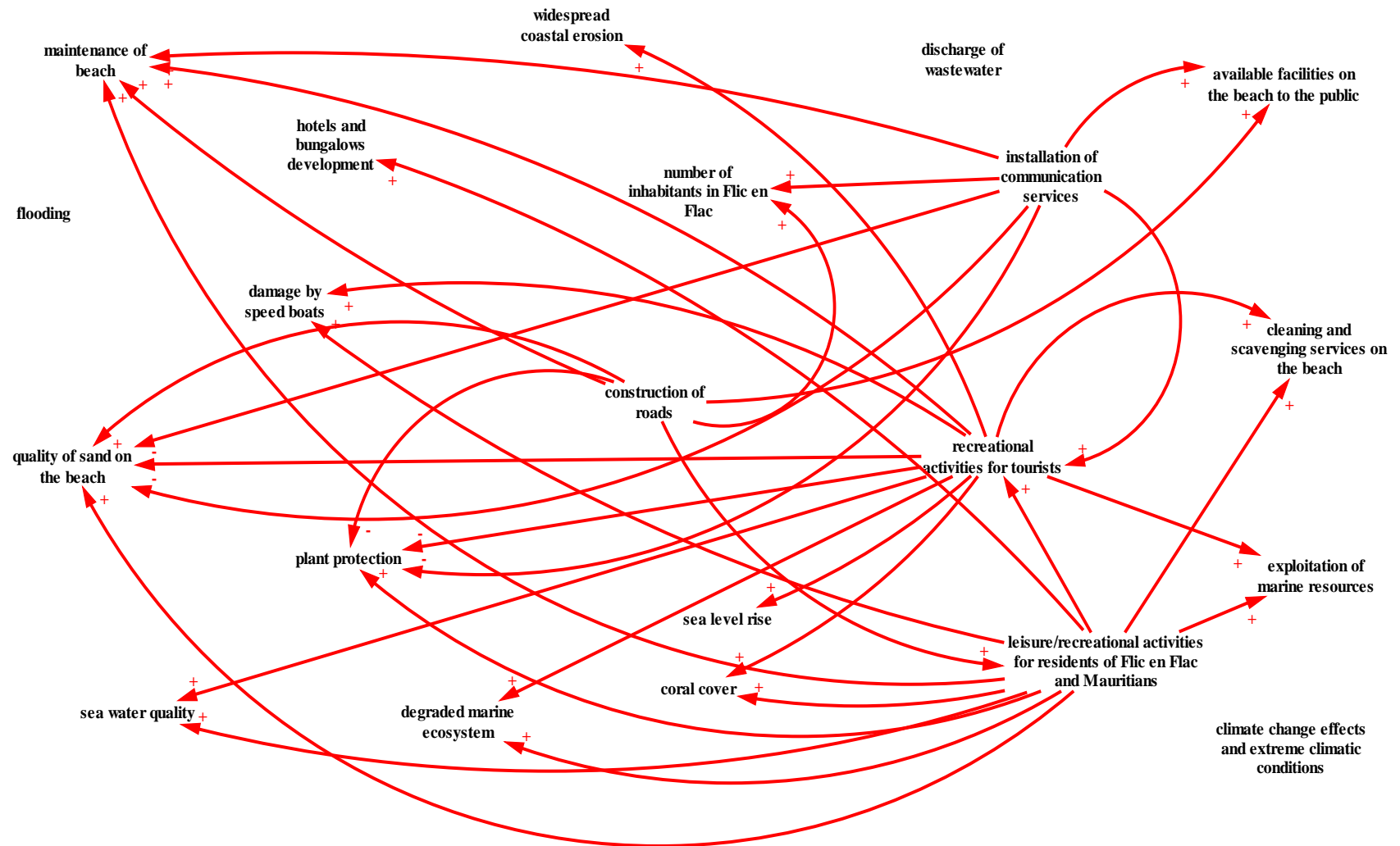
**Goal 1: To control further development of the undeveloped Flic en Flac coastal zone.**



**Goal 2: To protect, enhance and celebrate natural and cultural diversity.**

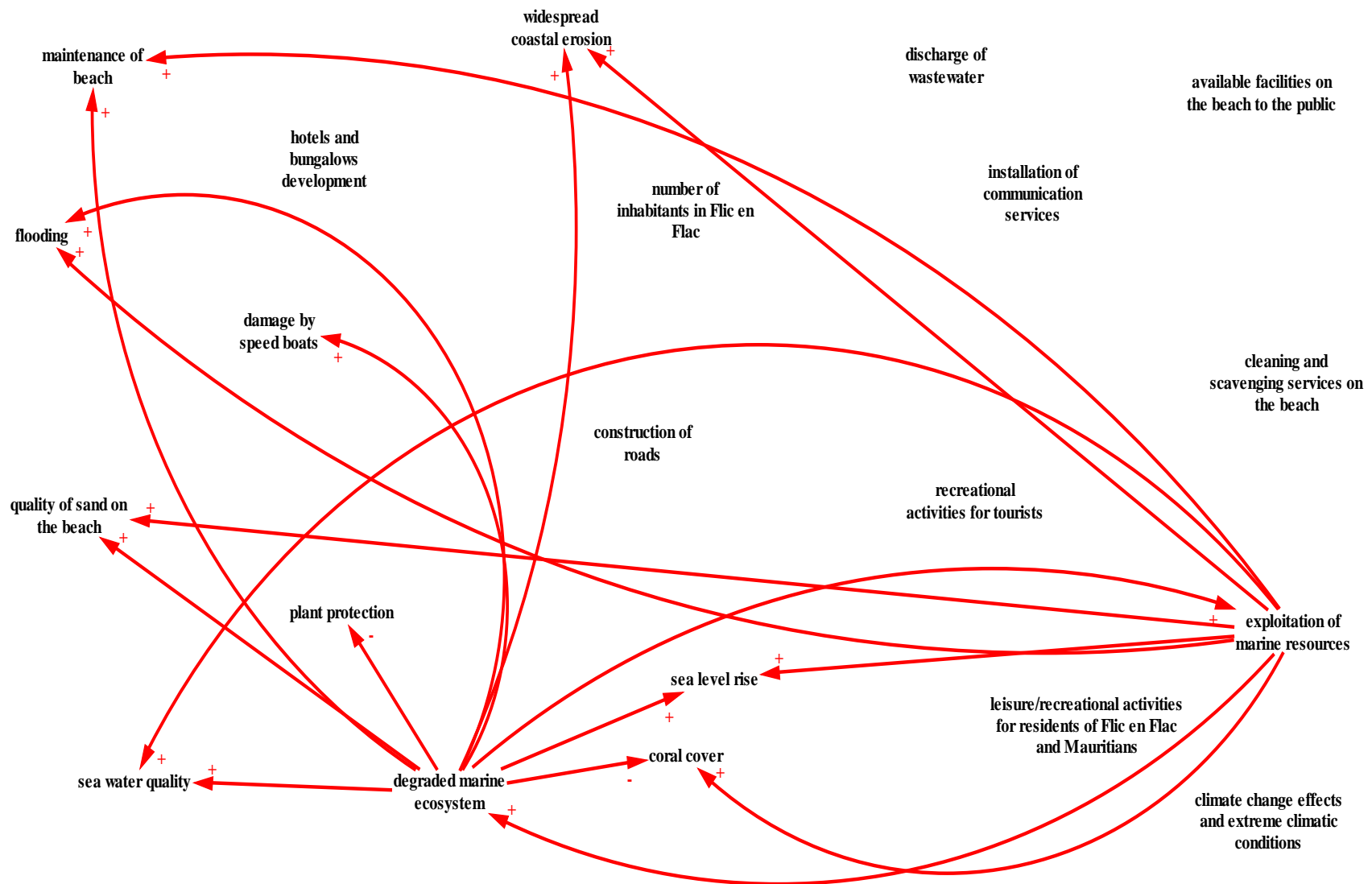


**Goal 3: To promote and support a dynamic and sustainable coastal economy.**





## Goal 5: To use natural resources wisely.







### 3.5 Ranking of Variables in Terms of Importance

Based on the stakeholders' views, the ranking of the variables has been calculated using the formula.

		GOAL 1			GOAL 2		GOAL 3				GOAL 4					GOAL 5		GOAL 6			I <sub>VH</sub>	
		V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17	V18	V19		V20
GOAL 1	V1			2+						2+												4
	V2	13+		13+			13+			13+	13+				11+	13+					89	
	V3	13+			13+			13+	13+					13+	4+	13+					82	
GOAL 2	V4	13-		13-		13-	13-	13-	13-	13+	13-	13-	13-	13+	13-	13-	13-		13-	13-	13-	221
	V5	13+	13+	11+	11-		13+			13+	13+	2+	13+	11-		11+	13+	13+	13+	13+	13+	189
GOAL 3	V6	13+		2+					13+	2+					2+							32
	V7	13+		13+																	26	
	V8	13+		13+				13+													39	
	V9	13+		13+										13+		13+					52	
GOAL 4	V10		13+	13+	11-	13+	13+	13+		13+		13+	13+	13-	13+	11+	13+	13+	13+	13+	13+	217
	V11	13+	13+	11+	11-		11+		11-	11+	13+		13+	11-	11-	11+	13+	11+	13+	13+	13+	203
	V12	13+		13+				13+						11+							50	
	V13	13+	13+	13+	13+	13+	13+		13+	13+	13+	13+	13+		13+	13+	13+	13+	13+	13+	234	
	V14	13+		13+			13+	13+		13+						13+					78	
	V15			13+					13+												26	
GOAL 5	V16	13+	13+	11+		13+	13+			13+	13+	13+	13+	2+	13-	11+		9+	13+	13+	11+	187
	V17	11+	13+	11+			13+			13+	13+		13+			13+	13+				113	
GOAL 6	V18	13+	4+	13+	11-	13+	13+				9+		9+	9+	13+	7+	4+	4+		13+	7+	142
	V19	4+	4+			7+	13+				4+	4+	4+				4+	4+			7+	55
	V20	11+	11+	11+		11+					11+	11+	11+	11-			11+	11+	13+	13+	13+	149
	I <sub>VV</sub>	208	97	202	70	83	141	78	76	119	115	69	115	107	82	140	110	78	91	104	103	2188

**Table 8: Ranking of Variables**

Goals	Variables		I <sub>VV</sub>	I <sub>VH</sub>	N <sub>OUT</sub>	Ranking	
GOAL 1	1.	Hotels and bungalows development	4	208	19	4028	2
	2.	Damage by speed boats and divers	89	97	10	1860	14
	3.	Number of inhabitants in Flic en Flac	82	202	19	5396	1
GOAL 2	4.	Protection of plants within the coastal zone of Flic en Flac	221	70	8	2328	7
	5.	Decrease in coral cover	189	83	10	2720	6
GOAL 3	6.	Recreational activities for tourists	32	141	12	2076	11
	7.	Construction of roads	26	78	8	832	20
	8.	Installation of communication services	39	76	8	920	19
	9.	Leisure/recreational activities for residents of Flic en Flac and Mauritians	52	119	12	2052	12
GOAL 4	10.	Sea water quality	217	115	11	3652	3
	11.	Quality of sand on the beach	203	69	8	2176	9
	12.	Discharge of wastewater	50	115	11	1815	16
	13.	Cleaning and scavenging services on the beach of Flic en Flac	234	107	9	3069	5
	14.	Available facilities on the beach to the public	78	82	14	2240	8
	15.	Maintenance of Flic en Flac beach	26	140	11	1826	15
GOAL 5	16.	Degraded marine ecosystem	187	110	11	3267	4
	17.	Exploitation of marine resources	113	78	11	2101	10
GOAL 6	18.	Widespread coastal erosion	142	91	8	1864	13
	19.	Climate change effects and extreme climatic conditions	55	104	9	1431	17
	20.	Flooding	149	10	9	1431	17

**Table 9: Ranking of variables in terms of importance**

<b>Ranking of Variables in terms of Importance</b>	
1.	Number of inhabitants in Flic en Flac
2.	Hotels and bungalows development
3.	Sea water quality
4.	Degraded marine ecosystem
5.	Cleaning and scavenging services on the beach of Flic en Flac
6.	Decrease in coral cover
7.	Protection of plants within the coastal zone of Flic en Flac
8.	Available facilities on the beach to the public
9.	Quality of sand on the beach
10.	Exploitation of marine resources
11.	Recreational activities for tourists
12.	Leisure/recreational activities for residents of Flic en Flac and Mauritians
13.	Widespread coastal erosion
14.	Damage by speed boats and divers
15.	Maintenance of Flic en Flac beach
16.	Discharge of wastewater
17.	Climate change effects and extreme climatic conditions
18.	Flooding
19.	Installation of communication services
20.	Construction of roads

### 3.6 Indicators and relevant measurements for the Flic en Flac demo site

The indicators as well as the measurements have been identified based on the coastal zone issues prevailing in the demo site.

**Table 10: Indicators and Measurements for Flic en Flac demo site**

<b>Goal 1: To control further development of the undeveloped Flic en Flac coastal zone.</b>	
<b>Indicators</b>	<b>Measurements</b>
1. Land use change and degradation	<ul style="list-style-type: none"> <li>- Percentage of arable and permanent crop area</li> <li>- Share of land protected by law</li> <li>- Percentage degraded land due to natural processes or human activities</li> <li>- Area of built land</li> <li>- Percentage of built land by distance from the coastline</li> <li>- Percentage of pas géométrique</li> </ul>
2. Coastal touristic development	<ul style="list-style-type: none"> <li>- Number of tourist accommodation</li> <li>- Number of building permits issued</li> <li>- Number of restaurants and food shops</li> <li>- Number of commercial buildings</li> <li>- Number of jetties</li> <li>- Area of land converted from non-developed to developed uses</li> </ul>
3. Demand for property on the coast	<ul style="list-style-type: none"> <li>- Residential population of Flic en Flac</li> <li>- Area of developed land for residents</li> <li>- Residential property value</li> </ul>
4. Population growth rate	<ul style="list-style-type: none"> <li>- Size of population</li> <li>- Number of still births</li> <li>- Mortality rate</li> </ul>
<b>Goal 2: To protect, enhance and celebrate natural and cultural diversity.</b>	
<b>Indicators</b>	<b>Measurements</b>
5. Fragmentation of habitat	<ul style="list-style-type: none"> <li>- Fragmentation of identified key habitats</li> <li>- Area of natural habitat</li> <li>- Rate of loss/damage of protected areas</li> <li>- Area of land protected for nature conservation</li> </ul>
6. Threat status of species	<ul style="list-style-type: none"> <li>- Status and trend of specified habitats and species</li> <li>- Number of species per type of habitat</li> <li>- Number of species as per the IUCN Red List</li> <li>- Population trends in species</li> <li>- Number of taxa</li> <li>- Number of Invasive Alien Species (IAS)</li> </ul>
7. Coral reef ecosystems	<ul style="list-style-type: none"> <li>- Area of coral reef</li> <li>- Percentage live coral cover</li> <li>- Percentage of hard cover coral</li> </ul>

<b>Goal 3: To promote and support a dynamic and sustainable coastal economy.</b>	
<b>Indicators</b>	<b>Measurements</b>
8. Pressure for coastal and marine recreation	<ul style="list-style-type: none"> <li>- Number and types of activities within the coastal zone</li> <li>- Number of issues licenses</li> <li>- Number of recreation amenities/opportunities</li> <li>- Intensity of use of recreational activities: land and water based</li> </ul>
9. Communication services	<ul style="list-style-type: none"> <li>- Proportion of the population with communication access</li> <li>- Network availability</li> <li>- Services provided by network operators</li> <li>- Number of mobile phone and fixed line subscribers</li> </ul>
10. Road network	<ul style="list-style-type: none"> <li>- Road length</li> <li>- Volume of traffic</li> </ul>
11. Employment	<ul style="list-style-type: none"> <li>- Ratio of employment to population</li> <li>- Status in employment: employees, employers, entrepreneurs</li> <li>- Output per unit of labour</li> </ul>
12. Education completion Rate	<ul style="list-style-type: none"> <li>- Number of full time, part time and seasonal employment per sector</li> <li>- Number of new entrants in pre-primary, primary, secondary and tertiary education</li> <li>- Number of children of official school age</li> <li>- Level of adult secondary school attainment</li> <li>- Percentage of adult population in education/training</li> <li>- Percentage of literate population</li> </ul>
<b>Goal 4: To ensure that beaches of Flic en Flac are clean and that coastal waters are unpolluted.</b>	
<b>Indicators</b>	<b>Measurements</b>
13. Water Resources	<ul style="list-style-type: none"> <li>- Volume of ground and surface potable water for human consumption</li> <li>- Volume of water for agricultural purpose</li> <li>- Microbial quality of water</li> <li>- Proportion of treated wastewater</li> </ul>
14. Bathing water quality	<ul style="list-style-type: none"> <li>- Bating water directive</li> <li>- Water quality tests for microbiological parameters</li> <li>- Water quality tests for physicochemical parameters</li> </ul>
15. Coastal zone litter	<ul style="list-style-type: none"> <li>- Volume of litter collected per given length of shoreline</li> <li>- Volume of litter collected by local authorities</li> <li>- Type of litter collected</li> <li>- Frequency of scavenging services</li> </ul>
16. Sand quality	<ul style="list-style-type: none"> <li>- Quality test of sand particles</li> <li>- Areas and volume of sand nourishment</li> </ul>

<b>Goal 5: To use natural resources wisely.</b>	
<b>Indicators</b>	<b>Measurements</b>
17. Marine resources index	<ul style="list-style-type: none"> <li>- Percentage of fish stocks exploited within the level of maximum biological productivity</li> <li>- Change in mean of the trophic level of fisheries per landing station</li> <li>- Quota of fish</li> <li>- Size of target spawning stocks</li> <li>- Catch Per Unit Effort (CPUE) for target fisheries</li> <li>- Type of gear used</li> <li>- Number of fish species caught per landing station</li> <li>- Value of landings per species</li> <li>- Landings and fish mortality per species</li> <li>- Number of registered fishermen</li> <li>- Fish stocks per species and area of sea</li> <li>- Percentage cover of benthic plants and animals</li> </ul>
<b>Goal 6: To recognize the threat to coastal zones posed by climate change and to ensure appropriate and ecologically responsible coastal protection.</b>	
<b>Indicators</b>	<b>Measurements</b>
18. Coastal erosion	<ul style="list-style-type: none"> <li>- Area of protected coastline</li> <li>- Length of dynamic coastline</li> </ul>
19. Sea level rise	<ul style="list-style-type: none"> <li>- Percentage of population living within 100 km from the coast and 50 meters above sea level</li> <li>- Height of sea level relative to land</li> </ul>
20. Vulnerability to coastal zone hazards	<ul style="list-style-type: none"> <li>- Type of coastal zone hazards</li> <li>- Percentage of population living in prone hazardous areas</li> <li>- Proportion of infrastructure in prone hazardous areas</li> </ul>

## **4.0 DISCUSSION**

### **4.1 Data collection**

#### **4.1.1 GOAL 1: To control further development of the undeveloped coast.**

##### **Hotels and bungalows development**

At present, in Flic en Flac, there are 14 hotels located on the beach each with different numbers of rooms and bed places. It has also been found out that there has been an increase in the types of building in Flic en Flac:

- i. building under construction and not inhabited
- ii. block of flats containing three or more housing units
- iii. tourist residence
- iv. commercial building and
- v. other non-residential building.

Furthermore, the number of building and land use permits for residents in the region of Flic en Flac has tremendously increased from the year 1993 to 2010 with very few decreases for the years 1995, 1999 and 2003. There has also been an increase in the number of tourists visiting Mauritius be it on business or on holidays. However, there has been a slight decrease in the number of tourists on transit in Mauritius. The 2011 census conducted by the CSO shows that there has been an increase in the population of Flic en Flac from the year 2000. The residents of Flic en Flac on the other hand have attained different levels of education with a greater proportion of the female population.

The building and construction of hotels, block of flats for tourist residence, commercial and non-residential building is mainly because of the number of incoming tourists in Mauritius. One of the set objectives of the Government of Mauritius is to make the touristic industry the leading growth sector of the economy by setting a target by the year 2015 to accommodate up to 2 million tourists per year (GIS, 2012). All hotels in Flic en Flac have been constructed along the beach. From an economic point of view, hotel construction and other related touristic business is a source of foreign revenue and generates employment (Bonamie, 2007). However, from an environmental perspective, studies have revealed that the topography of the beach is disturbed



when constructing along the beach and this is known as architectural pollution (Thullen S., 1996). This disturbance subsequently has negative effects on the coastal zone.

Moreover, Flic en Flac is considered as an important residential village of Mauritius and since past few years, there have been huge development in terms of morcellement. This is has therefore hugely increased the residential population as per the data of CSO.

#### **4.1.2 GOAL 3: To promote and support a dynamic and sustainable coastal economy.**

##### **Recreational activities for tourists, Leisure/recreational activities for residents of Flic en Flac and Mauritians**

The number of pleasure craft licences issued by the Tourism Authority for the region of Flic en Flac has increased from 10 to 69 from the year 2007 to the year 2012. Moreover, a large number of licences has been issued for accommodation, activities and tourist accommodation for Flic en Flac as at June 2012. From an economic perspective, these licences are essential to cater to the needs of tourists and also to Mauritians. Coastal recreation forms part of the tourism based activities and are increasing in number in order to satisfy the growing number of tourists. These activities unfortunately have direct effect on the coastal environment: being detrimental to the beach dwelling species, marine species and habitats (Milazzo M. *et al.*, 2002).

##### **Construction of roads**

There is only one road along the beach of Flic en Flac which is 736 metres long as per the Ministry of Public Infrastructure. Road network is a key element especially for the tourism sector for the Flic en Flac demo site (IRF, 2007). Moreover, road constructions have enabled other types of development to occur.

##### **Installation of communication services**

The three network operators: Emtel, Orange and MTML have installed relay services in the region of Flic en Flac. Emtel network operator has more relay sites in Flic en Flac.

#### **4.1.3 GOAL 4: To ensure that beaches of Flic en Flac are clean and that coastal waters are unpolluted.**

##### **Sea water quality**

Flic en Flac is a monitoring site for the Ministry of Fisheries for physico-chemical parameters of the sea water. These physico-chemical parameters: salinity, pH, Dissolved Oxygen (DO), Nitrate-Nitrogen level and Phosphate level are indications of the status of sea water, based on which the growth and distribution of marine organisms are dependent (Vaillancourt, 2003). Total and faecal coliform indicate that water is contaminated and is used for the evaluation of the quality of water (APEC, 2012).

##### **Discharge of wastewater**

Out of the 14 hotels in Flic en Flac, only 6 have installed waste water treatment plant. Treated effluents from these hotels are used for irrigation purposes within the hotels. The treatment of wastewater is essential as it removes organic as well as inorganic matter which may cause pollution and diseases (Neves R. *et al.*, 2002). This treatment helps in protecting the environment as well as human health. Furthermore, the disposal of wastewater in the sea disturbs the prevailing ecosystem which eventually leads to eutrophication (ACE, 2010). Eutrophication results in a disruption of the nutrients of the sea which in turn impacts the marine organisms (C. Lundberg, 2005).

##### **Cleaning and scavenging services on the beach of Flic en Flac**

The cleaning and scavenging services are carried out every day on the beach and village of Flic en Flac. The Ministry of Local Government has contracted out Securiclean and Mauritius Maxi Clean Company Limited companies for the collection of waste. Green waste is then transferred to La Chaumière Compost Plant while other types of waste are disposed at La Chaumière Transfer Station. Waste on the beach may be a source of pests and diseases, thus being a form of pollution (Dougall, *et al.* 2001). Moreover, a clean beach is attractive to tourists and also to visitors.

##### **Available facilities on the beach to the public**

Facilities in terms of amenities on the beach are essential to cater to the needs of tourists as well as visitors (Gunderson *et al.*, 2005). The beach authority has provided basic facilities on beaches around the island; this is in view to satisfy the needs of Mauritians as well as tourists (Beach

Authority, 2012). Furthermore, beach authority is responsible for the control as well as management of proclaimed public beaches with the aim of benefiting the public (Beach Authority, 2012). Only natural amenities are not sufficient to attract tourists to a region, hence the need of the provision of facilities (Bruce, 2010). While so doing, however, in some cases, the natural resources are not protected which irreversibly impact on the environment (Larose, 2011).

### **Maintenance of Flic en Flac beach**

The maintenance of the beach consists of daily sweeping of the beach. Furthermore, waste is collected twice per week in the village of Flic en Flac. Cleaning and maintenance of the beach is aesthetic. However, studies have revealed that raking or any other way of cleaning probably affects the fauna and flora of the beach and also impairs the nourishment of the beach (DFO, 2010, Greene K., 2005).

#### **4.1.4 GOAL 5: To use natural resources wisely.**

##### **Exploitation of marine resources**

Mauritius has an Exclusive Economic Zone of 1.9 million square kilometres which consists of a reasonable stock of pelagic and demersal fish species (AFRC annual report, 2007). The most common types of fisheries is a combination of industrial, semi industrial and artisanal fisheries and is subdivided into coastal fishery, industrialised tuna fisheries, deep demersal fishery and fish aggregating devices (AFRC annual report, 2007). The fisheries industry contributes to 1 % of the GDP of Mauritius and is a source of employment (FAO, 2010). Data of annual catch and effort of fisherman from the Ministry of Fisheries from the year 1993 shows a decreasing trend. According to the FAO, the global situation of fish stocks is that 52 % fully exploited, 17 % over exploited and 7 % depleted. (FAO, 2007). This may be explained by the fact that there has been an on-going over fishing of stocks especially juvenile fish and also because of lack of information about available stocks (FAO, 2002; Boyer *et al.*, 2005).

## 4.2 Missing data

Data for the following variables were not available:

GOAL	VARIABLES
<b>GOAL 1: To control further development of the undeveloped coast.</b>	- Damage by speed boats
<b>GOAL 2: To protect, enhance and celebrate natural and cultural diversity.</b>	- Protection of plants within the coastal zone of Flic en Flac - Decrease in coral cover - Quality of sand on the beach
<b>GOAL 5: To use natural resources wisely.</b>	- Degraded marine ecosystem
<b>GOAL 6: To recognize the threat to coastal zones posed by climate change and to ensure appropriate and ecologically responsible coastal protection.</b>	- Widespread coastal erosion - Climate change effects and extreme climatic conditions - Flooding

### 4.3 Identification of Indicators for the demo site of Flic en Flac

Indicators are information that may be quantified in view of showing the change of a particular variable with time (Simon S., 2003). Indicators help in decision making and enables stakeholders to effectively choose the best actions: by simplifying, clarifying and aggregating complex quantifiable information (Bartelmus P., 2008). They are also useful tools to communicate ideas, thoughts and values. Indicators for Flic en Flac have been identified based on the prevailing coastal zone variables.

**Table 11: Short description of indicators**

<b>Indicator</b>		<b>Description</b>
1.	Land use change and degradation	This indicator is a measurement of the change in land within the demo site of Flic en Flac. It also includes the temporary or permanent in the productivity of the land owing to anthropogenic factors/activities.
2.	Coastal touristic development	It quantifies the development that has occurred as a result of incoming tourists in the demo site of Flic en Flac. These developments are all in view of catering tourists and also Mauritians visiting Flic en Flac.
3.	Demand for property on the coast	Coastal zones tend to be an area of convergence for residents and there is a need to monitor pressure on the coastal zone of Flic en Flac in terms of population and demand for land.
4.	Population growth rate	This indicator measures the change in the size of the population of the Flic en Flac demo site.
5.	Fragmentation of habitat	Fragmentation of key habitat as a result of human activities may be measured using this indicator.
6.	Threat status of species	The indicator is a measurement of the trend of species and taxa.
7.	Coral reef ecosystems	Trends in the changes in the extent of coral reefs may be measured through this indicator.
8.	Pressure for coastal and marine recreation	This indicator measures the proportion of coastal and marine area designated for recreation.
9.	Communication services	Measurement of availability of communication services: networks and related services and telecommunication development.

10.	Road network	This indicator provides information on the mode of transport and number of vehicles.
11.	Employment	Proportion of the working population of the region of flic en Flac is an indicator of the economically active population.
12.	Education completion rate	This indicator is a measurement of the eligibility of the school age population and the education level of the population.
13.	Water resources	It indicates the degree to which freshwater is being exploited for human consumption and the quality of freshwater as well as treated wastewater.
14.	Bathing water quality	This indicator is a description of bathing water quality changes with time according standard microbial and physico parameters.
15.	Coastal zone litter	Measurement of amount of litter collected and the frequency of collection of wastes by concerned authorities.
16.	Sand quality	This indicator measures the quality of the sand in terms of the grain size and nourishment of the beach.
17.	Marine resources index	Measurement of the change in the number of fish stocks, landings, quotas, types of gears and number of fishermen.
18.	Coastal erosion	This indicator describes the extent of eroded beach.
19.	Sea level rise	Measurement of the rise in the level of the sea, i.e. this will eventually define the shoreline and coastal zone.
20.	Vulnerability to coastal zone hazards	Indicates the level of vulnerability to natural hazards within the coastal zone thus aiding in preparing for any eventual natural catastrophes.

#### 4.4 Scenario Analysis

Scenario analysis is used as a standard tool for medium to long term strategic planning (Robinson, 2003). The focus of scenario analysis is to develop plausible alternative future pictures in which an operation might be implemented (Swart R.J *et al.*, 2004). The advantage of scenario analysis is that is a tool that plans for the future (Notten V., 2002). Scenario analysis has been carried out for the set of identified indicators to qualitatively see plausible future scenarios. For the purpose of this project work, three scenarios have been used as in Table 12 below:

**Table 12: Scenarios**

<b>Scenario 1</b>	Increase
<b>Scenario 2</b>	Unchanged
<b>Scenario 3</b>	Decrease

The identified indicators for Flic en Flac demo site have been analysed based on the three scenarios and the corresponding effects have been used:

EFFECT	
<b>Reinforcing</b>	<b>R</b>
<b>Static</b>	<b>S</b>
<b>Balancing</b>	<b>B</b>

For this study, the terms reinforcing, static and balancing have been used as follows:

<b>Reinforcing</b>	An indicator causes an increase of the other indicator.
<b>Static</b>	Static means that the indicator does not have any effect on other indicators.
<b>Balancing</b>	An increase/decrease in the indicator causes a subsequent increase/decrease in other indicators.

## Indicator 1: Land use change and degradation

	Land use change and degradation		
	Scenario 1	Scenario 2	Scenario 3
Coastal touristic development	<b>B</b>	<b>B</b>	<b>B</b>
Demand for property on the coast	<b>B</b>	<b>B</b>	<b>S</b>
Population growth rate	<b>B</b>	<b>R</b>	
Fragmentation of habitat	<b>R</b>	<b>B</b>	
Threat status of species	<b>R</b>	<b>B</b>	
Coral reef ecosystems	<b>R</b>	<b>B</b>	<b>B</b>
Pressure for coastal and marine recreation	<b>R</b>	<b>B</b>	<b>B</b>
Communication services	<b>S</b>	<b>S</b>	<b>S</b>
Road network	<b>S</b>	<b>S</b>	<b>S</b>
Employment	<b>S</b>	<b>S</b>	<b>S</b>
Education completion Rate		<b>S</b>	
Water Resources	<b>R</b>	<b>R</b>	<b>B</b>
Bathing water quality	<b>R</b>	<b>R</b>	<b>B</b>
Coastal zone litter	<b>R</b>	<b>B</b>	<b>B</b>
Sand quality	<b>R</b>	<b>B</b>	<b>B</b>
Marine resources index	<b>R</b>	<b>R</b>	
Coastal erosion	<b>R</b>	<b>R</b>	<b>B</b>
Sea level rise			
Vulnerability to coastal zone hazards	<b>R</b>	<b>R</b>	<b>R</b>



## Indicator 2: Coastal touristic development

	Coastal touristic development		
	Scenario 1	Scenario 2	Scenario 3
Land use change and degradation	<b>R</b>	<b>B</b>	<b>S</b>
Demand for property on the coast	<b>R</b>	<b>B</b>	<b>S</b>
Population growth rate	<b>R</b>		
Fragmentation of habitat	<b>R</b>	<b>B</b>	
Threat status of species	<b>R</b>	<b>B</b>	
Coral reef ecosystems	<b>R</b>	<b>B</b>	
Pressure for coastal and marine recreation	<b>R</b>	<b>B</b>	<b>B</b>
Communication services	<b>R</b>	<b>S</b>	<b>S</b>
Road network	<b>R</b>	<b>S</b>	<b>S</b>
Employment	<b>R</b>		<b>S</b>
Education completion Rate			
Water Resources	<b>R</b>	<b>B</b>	<b>B</b>
Bathing water quality	<b>R</b>		<b>B</b>
Coastal zone litter	<b>R</b>	<b>R</b>	<b>B</b>
Sand quality	<b>R</b>	<b>R</b>	<b>B</b>
Marine resources index	<b>R</b>	<b>R</b>	<b>B</b>
Coastal erosion	<b>R</b>	<b>R</b>	<b>B</b>
Sea level rise			
Vulnerability to coastal zone hazards	<b>R</b>	<b>R</b>	<b>B</b>

### Indicator 3: Demand for property on the coast

	Demand for property on the coast		
	Scenario 1	Scenario 2	Scenario 3
Land use change and degradation	<b>R</b>	<b>R</b>	<b>S</b>
Coastal touristic development	<b>R</b>	<b>R</b>	<b>S</b>
Population growth rate	<b>R</b>	<b>B</b>	
Fragmentation of habitat	<b>R</b>	<b>B</b>	
Threat status of species	<b>R</b>	<b>B</b>	<b>B</b>
Coral reef ecosystems	<b>R</b>	<b>B</b>	<b>B</b>
Pressure for coastal and marine recreation	<b>R</b>	<b>B</b>	<b>B</b>
Communication services	<b>R</b>	<b>S</b>	<b>S</b>
Road network	<b>R</b>	<b>S</b>	<b>S</b>
Employment	<b>R</b>	<b>S</b>	<b>S</b>
Education completion Rate			
Water Resources	<b>R</b>	<b>B</b>	<b>B</b>
Bathing water quality	<b>R</b>	<b>B</b>	<b>B</b>
Coastal zone litter	<b>R</b>	<b>B</b>	<b>B</b>
Sand quality	<b>R</b>	<b>B</b>	<b>B</b>
Marine resources index	<b>R</b>	<b>B</b>	<b>B</b>
Coastal erosion	<b>R</b>	<b>B</b>	<b>B</b>
Sea level rise			
Vulnerability to coastal zone hazards	<b>R</b>	<b>B</b>	<b>S</b>

#### Indicator 4: Population growth rate

	Population growth rate		
	Scenario 1	Scenario 2	Scenario 3
Land use change and degradation	<b>R</b>	<b>R</b>	<b>S</b>
Coastal touristic development	<b>R</b>	<b>B</b>	<b>S</b>
Demand for property on the coast	<b>R</b>	<b>R</b>	<b>S</b>
Fragmentation of habitat	<b>R</b>	<b>B</b>	<b>S</b>
Threat status of species	<b>R</b>	<b>B</b>	<b>S</b>
Coral reef ecosystems	<b>R</b>	<b>B</b>	<b>S</b>
Pressure for coastal and marine recreation	<b>R</b>	<b>B</b>	<b>S</b>
Communication services	<b>R</b>	<b>S</b>	<b>B</b>
Road network	<b>R</b>	<b>S</b>	<b>B</b>
Employment	<b>B</b>	<b>S</b>	<b>B</b>
Education completion Rate	<b>B</b>		
Water Resources	<b>R</b>	<b>B</b>	<b>B</b>
Bathing water quality	<b>R</b>	<b>B</b>	<b>S</b>
Coastal zone litter	<b>R</b>	<b>B</b>	
Sand quality	<b>R</b>	<b>B</b>	
Marine resources index	<b>R</b>	<b>B</b>	<b>B</b>
Coastal erosion	<b>B</b>	<b>B</b>	<b>B</b>
Sea level rise		<b>S</b>	
Vulnerability to coastal zone hazards	<b>B</b>	<b>S</b>	

## Indicator 5: Fragmentation of habitat

	Fragmentation of habitat		
	Scenario 1	Scenario 2	Scenario 3
Land use change and degradation	S	S	S
Coastal touristic development	S	S	S
Demand for property on the coast	S	S	S
Population growth rate	S	S	S
Threat status of species	R	S	B
Coral reef ecosystems	R	S	B
Pressure for coastal and marine recreation	S	S	S
Communication services	S	S	S
Road network	S	S	S
Employment	S	S	S
Education completion Rate	S	S	S
Water Resources	S	S	S
Bathing water quality	S	S	S
Coastal zone litter	S	S	S
Sand quality	S	S	S
Marine resources index	R	S	B
Coastal erosion	S	S	S
Sea level rise	S	S	S
Vulnerability to coastal zone hazards	S	S	S

## Indicator 6: Threat status of species

	Threat status of species		
	Scenario 1	Scenario 2	Scenario 3
Land use change and degradation	S	S	S
Coastal touristic development	S	S	S
Demand for property on the coast	S	S	S
Population growth rate	S	S	S
Fragmentation of habitat	R	S	B
Coral reef ecosystems	R	S	B
Pressure for coastal and marine recreation	S	S	S
Communication services	S	S	S
Road network	S	S	S
Employment	S	S	S
Education completion Rate	S	S	S
Water Resources	S	S	S
Bathing water quality	R	S	B
Coastal zone litter	S	S	S
Sand quality	S	S	S
Marine resources index	R	S	B
Coastal erosion	S	S	S
Sea level rise	S	S	S
Vulnerability to coastal zone hazards	S	S	S

## Indicator 7: Coral reef ecosystems

	Coral reef ecosystems		
	Scenario 1	Scenario 2	Scenario 3
Land use change and degradation	<b>B</b>		<b>R</b>
Coastal touristic development	<b>B</b>	<b>S</b>	<b>R</b>
Demand for property on the coast	<b>B</b>		<b>R</b>
Population growth rate	<b>B</b>	<b>S</b>	<b>B</b>
Fragmentation of habitat	<b>R</b>	<b>S</b>	<b>B</b>
Threat status of species	<b>R</b>		<b>B</b>
Pressure for coastal and marine recreation	<b>R</b>	<b>S</b>	<b>S</b>
Communication services	<b>S</b>	<b>S</b>	<b>S</b>
Road network	<b>S</b>	<b>S</b>	<b>S</b>
Employment	<b>S</b>	<b>S</b>	<b>S</b>
Education completion Rate	<b>S</b>	<b>S</b>	<b>S</b>
Water Resources	<b>R</b>	<b>S</b>	<b>S</b>
Bathing water quality	<b>R</b>	<b>S</b>	<b>B</b>
Coastal zone litter	<b>S</b>	<b>S</b>	<b>S</b>
Sand quality	<b>R</b>		<b>B</b>
Marine resources index	<b>R</b>		<b>B</b>
Coastal erosion	<b>R</b>		<b>B</b>
Sea level rise	<b>R</b>		<b>B</b>
Vulnerability to coastal zone hazards	<b>R</b>		<b>B</b>

## Indicator 8: Pressure for coastal and marine recreation

	Pressure for coastal and marine recreation		
	Scenario 1	Scenario 2	Scenario 3
Land use change and degradation	<b>R</b>	<b>S</b>	<b>R</b>
Coastal touristic development	<b>B</b>	<b>R</b>	<b>R</b>
Demand for property on the coast	<b>B</b>	<b>R</b>	<b>R</b>
Population growth rate	<b>B</b>	<b>S</b>	
Fragmentation of habitat	<b>R</b>	<b>S</b>	<b>B</b>
Threat status of species	<b>R</b>	<b>S</b>	<b>B</b>
Coral reef ecosystems	<b>R</b>	<b>S</b>	<b>B</b>
Communication services	<b>S</b>		
Road network	<b>S</b>		
Employment	<b>S</b>		
Education completion Rate	<b>S</b>		
Water Resources	<b>S</b>	<b>S</b>	
Bathing water quality	<b>R</b>	<b>S</b>	<b>B</b>
Coastal zone litter	<b>B</b>	<b>S</b>	
Sand quality	<b>R</b>	<b>S</b>	<b>B</b>
Marine resources index	<b>R</b>	<b>S</b>	<b>B</b>
Coastal erosion	<b>R</b>	<b>S</b>	<b>B</b>
Sea level rise	<b>R</b>	<b>S</b>	<b>B</b>
Vulnerability to coastal zone hazards	<b>R</b>	<b>S</b>	<b>B</b>

## Indicator 9: Communication services

	Communication services		
	Scenario 1	Scenario 2	Scenario 3
Land use change and degradation	<b>R</b>	<b>B</b>	<b>B</b>
Coastal touristic development	<b>R</b>	<b>B</b>	<b>B</b>
Demand for property on the coast	<b>R</b>	<b>B</b>	<b>B</b>
Population growth rate	<b>R</b>	<b>B</b>	<b>B</b>
Fragmentation of habitat	<b>R</b>	<b>B</b>	<b>B</b>
Threat status of species	<b>R</b>	<b>B</b>	<b>B</b>
Coral reef ecosystems	<b>R</b>	<b>B</b>	<b>B</b>
Pressure for coastal and marine recreation	<b>R</b>	<b>B</b>	<b>B</b>
Road network	<b>R</b>	<b>B</b>	<b>B</b>
Employment	<b>R</b>	<b>B</b>	<b>B</b>
Education completion Rate			
Water Resources	<b>R</b>	<b>B</b>	<b>B</b>
Bathing water quality	<b>R</b>	<b>B</b>	<b>B</b>
Coastal zone litter	<b>R</b>	<b>B</b>	<b>B</b>
Sand quality	<b>R</b>	<b>B</b>	<b>B</b>
Marine resources index	<b>R</b>	<b>B</b>	<b>B</b>
Coastal erosion	<b>R</b>	<b>B</b>	<b>B</b>
Sea level rise		<b>B</b>	
Vulnerability to coastal zone hazards	<b>R</b>	<b>B</b>	<b>B</b>



## Indicator 10: Road network

	Road network		
	Scenario 1	Scenario 2	Scenario 3
Land use change and degradation	<b>R</b>	<b>B</b>	<b>B</b>
Coastal touristic development	<b>R</b>	<b>B</b>	<b>B</b>
Demand for property on the coast	<b>R</b>	<b>B</b>	<b>B</b>
Population growth rate	<b>R</b>	<b>B</b>	<b>B</b>
Fragmentation of habitat	<b>R</b>	<b>B</b>	<b>B</b>
Threat status of species	<b>R</b>	<b>B</b>	<b>B</b>
Coral reef ecosystems	<b>R</b>	<b>B</b>	<b>B</b>
Pressure for coastal and marine recreation	<b>R</b>	<b>B</b>	<b>B</b>
Communication services	<b>R</b>	<b>B</b>	<b>B</b>
Employment	<b>R</b>	<b>B</b>	<b>B</b>
Education completion Rate			
Water Resources	<b>R</b>	<b>B</b>	<b>B</b>
Bathing water quality	<b>R</b>	<b>B</b>	<b>B</b>
Coastal zone litter	<b>R</b>	<b>B</b>	<b>B</b>
Sand quality	<b>R</b>	<b>B</b>	<b>B</b>
Marine resources index	<b>R</b>	<b>B</b>	<b>B</b>
Coastal erosion	<b>R</b>	<b>B</b>	<b>B</b>
Sea level rise			
Vulnerability to coastal zone hazards	<b>R</b>	<b>B</b>	<b>B</b>

## Indicator 11: Employment

	Employment		
	Scenario 1	Scenario 2	Scenario 3
Land use change and degradation	<b>R</b>	<b>B</b>	<b>B</b>
Coastal touristic development	<b>R</b>	<b>B</b>	<b>B</b>
Demand for property on the coast	<b>R</b>	<b>B</b>	<b>B</b>
Population growth rate	<b>R</b>	<b>B</b>	<b>B</b>
Fragmentation of habitat	<b>R</b>	<b>B</b>	<b>B</b>
Threat status of species	<b>R</b>	<b>B</b>	<b>B</b>
Coral reef ecosystems	<b>R</b>	<b>B</b>	<b>B</b>
Pressure for coastal and marine recreation	<b>R</b>	<b>B</b>	<b>B</b>
Communication services	<b>R</b>	<b>B</b>	<b>B</b>
Road network	<b>R</b>	<b>B</b>	<b>B</b>
Education completion Rate	<b>R</b>	<b>B</b>	<b>S</b>
Water Resources	<b>R</b>	<b>B</b>	<b>B</b>
Bathing water quality	<b>R</b>	<b>B</b>	<b>B</b>
Coastal zone litter	<b>R</b>	<b>B</b>	<b>B</b>
Sand quality	<b>R</b>	<b>B</b>	<b>B</b>
Marine resources index	<b>R</b>	<b>B</b>	<b>B</b>
Coastal erosion	<b>R</b>	<b>B</b>	<b>B</b>
Sea level rise			
Vulnerability to coastal zone hazards	<b>R</b>	<b>B</b>	<b>B</b>

## Indicator 12: Education completion Rate

	Education completion Rate		
	Scenario 1	Scenario 2	Scenario 3
Land use change and degradation	<b>B</b>	<b>S</b>	<b>R</b>
Coastal touristic development	<b>B</b>	<b>S</b>	<b>R</b>
Demand for property on the coast	<b>B</b>	<b>S</b>	<b>R</b>
Population growth rate	<b>B</b>	<b>S</b>	<b>R</b>
Fragmentation of habitat	<b>B</b>	<b>S</b>	<b>R</b>
Threat status of species	<b>B</b>	<b>S</b>	<b>R</b>
Coral reef ecosystems	<b>B</b>	<b>S</b>	<b>R</b>
Pressure for coastal and marine recreation	<b>B</b>	<b>S</b>	<b>R</b>
Communication services	<b>B</b>	<b>S</b>	
Road network	<b>B</b>	<b>S</b>	
Employment	<b>B</b>	<b>S</b>	
Water Resources	<b>B</b>	<b>S</b>	<b>R</b>
Bathing water quality	<b>B</b>	<b>S</b>	<b>R</b>
Coastal zone litter	<b>B</b>	<b>S</b>	<b>R</b>
Sand quality	<b>B</b>	<b>S</b>	<b>R</b>
Marine resources index	<b>B</b>	<b>S</b>	<b>R</b>
Coastal erosion	<b>B</b>	<b>S</b>	<b>R</b>
Sea level rise	<b>B</b>	<b>S</b>	<b>R</b>
Vulnerability to coastal zone hazards	<b>B</b>	<b>S</b>	<b>R</b>

### Indicator 13: Water Resources

	Water Resources		
	Scenario 1	Scenario 2	Scenario 3
Land use change and degradation	<b>R</b>	<b>B</b>	<b>S</b>
Coastal touristic development	<b>R</b>	<b>B</b>	<b>S</b>
Demand for property on the coast	<b>R</b>	<b>B</b>	<b>S</b>
Population growth rate	<b>R</b>	<b>B</b>	<b>B</b>
Fragmentation of habitat	<b>R</b>	<b>B</b>	<b>B</b>
Threat status of species	<b>R</b>	<b>B</b>	<b>B</b>
Coral reef ecosystems	<b>R</b>	<b>B</b>	<b>B</b>
Pressure for coastal and marine recreation	<b>R</b>	<b>B</b>	<b>B</b>
Communication services	<b>S</b>	<b>S</b>	<b>S</b>
Road network	<b>S</b>	<b>S</b>	<b>S</b>
Employment	<b>S</b>	<b>S</b>	<b>S</b>
Education completion Rate	<b>S</b>	<b>S</b>	<b>S</b>
Bathing water quality	<b>R</b>	<b>B</b>	<b>B</b>
Coastal zone litter	<b>S</b>	<b>S</b>	<b>S</b>
Sand quality	<b>S</b>	<b>S</b>	<b>S</b>
Marine resources index	<b>R</b>	<b>B</b>	<b>B</b>
Coastal erosion	<b>S</b>	<b>S</b>	<b>S</b>
Sea level rise	<b>B</b>	<b>S</b>	<b>B</b>
Vulnerability to coastal zone hazards	<b>B</b>	<b>B</b>	<b>B</b>

#### Indicator 14: Bathing water quality

	Bathing water quality		
	Scenario 1	Scenario 2	Scenario 3
Land use change and degradation	<b>R</b>	<b>S</b>	<b>B</b>
Coastal touristic development	<b>B</b>	<b>S</b>	<b>R</b>
Demand for property on the coast	<b>B</b>	<b>S</b>	<b>R</b>
Population growth rate	<b>B</b>	<b>S</b>	<b>R</b>
Fragmentation of habitat	<b>B</b>	<b>S</b>	<b>R</b>
Threat status of species	<b>B</b>	<b>S</b>	<b>R</b>
Coral reef ecosystems	<b>B</b>	<b>S</b>	<b>R</b>
Pressure for coastal and marine recreation	<b>B</b>	<b>S</b>	<b>R</b>
Communication services	<b>S</b>		<b>S</b>
Road network	<b>S</b>		<b>S</b>
Employment	<b>S</b>		<b>S</b>
Education completion Rate			
Water resources	<b>B</b>	<b>S</b>	<b>R</b>
Coastal zone litter			
Sand quality	<b>B</b>	<b>S</b>	<b>R</b>
Marine resources index	<b>R</b>	<b>S</b>	<b>B</b>
Coastal erosion	<b>B</b>	<b>S</b>	<b>R</b>
Sea level rise	<b>B</b>	<b>S</b>	<b>R</b>
Vulnerability to coastal zone hazards	<b>R</b>	<b>S</b>	<b>B</b>

## Indicator 15: Coastal zone litter

	Coastal zone litter		
	Scenario 1	Scenario 2	Scenario 3
Land use change and degradation	<b>R</b>	<b>S</b>	<b>R</b>
Coastal touristic development	<b>B</b>	<b>S</b>	<b>R</b>
Demand for property on the coast	<b>B</b>	<b>S</b>	<b>R</b>
Population growth rate	<b>B</b>	<b>S</b>	<b>R</b>
Fragmentation of habitat	<b>B</b>	<b>S</b>	<b>R</b>
Threat status of species	<b>B</b>	<b>S</b>	<b>R</b>
Coral reef ecosystems	<b>B</b>	<b>S</b>	<b>R</b>
Pressure for coastal and marine recreation	<b>B</b>	<b>S</b>	<b>R</b>
Communication services	<b>S</b>		<b>S</b>
Road network	<b>S</b>		<b>S</b>
Employment	<b>S</b>		<b>S</b>
Education completion Rate			
Water resources	<b>B</b>	<b>S</b>	<b>R</b>
Bathing water quality			
Sand quality	<b>B</b>	<b>S</b>	<b>R</b>
Marine resources index	<b>R</b>	<b>S</b>	<b>R</b>
Coastal erosion	<b>B</b>	<b>S</b>	<b>R</b>
Sea level rise	<b>B</b>	<b>S</b>	<b>R</b>
Vulnerability to coastal zone hazards	<b>R</b>	<b>S</b>	<b>R</b>

## Indicator 16: Sand quality

	Sand quality		
	Scenario 1	Scenario 2	Scenario 3
Land use change and degradation	<b>R</b>	<b>S</b>	<b>R</b>
Coastal touristic development	<b>B</b>	<b>S</b>	<b>R</b>
Demand for property on the coast	<b>B</b>	<b>S</b>	<b>R</b>
Population growth rate	<b>B</b>	<b>S</b>	<b>R</b>
Fragmentation of habitat	<b>B</b>	<b>S</b>	<b>R</b>
Threat status of species	<b>B</b>	<b>S</b>	<b>R</b>
Coral reef ecosystems	<b>B</b>	<b>S</b>	<b>R</b>
Pressure for coastal and marine recreation	<b>B</b>	<b>S</b>	<b>R</b>
Communication services	<b>S</b>		<b>S</b>
Road network	<b>S</b>		<b>S</b>
Employment	<b>S</b>		<b>S</b>
Education completion Rate			
Water resources	<b>B</b>	<b>S</b>	<b>R</b>
Bathing water quality			
Coastal zone litter	<b>B</b>	<b>S</b>	<b>R</b>
Marine resources index	<b>R</b>	<b>S</b>	<b>R</b>
Coastal erosion	<b>B</b>	<b>S</b>	<b>R</b>
Sea level rise	<b>B</b>	<b>S</b>	<b>R</b>
Vulnerability to coastal zone hazards	<b>R</b>	<b>S</b>	<b>R</b>

## Indicator 17: Marine resources index

	Marine resources index		
	Scenario 1	Scenario 2	Scenario 3
Land use change and degradation	<b>R</b>	<b>S</b>	<b>R</b>
Coastal touristic development	<b>B</b>	<b>S</b>	<b>R</b>
Demand for property on the coast	<b>B</b>	<b>S</b>	<b>R</b>
Population growth rate	<b>B</b>	<b>S</b>	<b>R</b>
Fragmentation of habitat	<b>B</b>	<b>S</b>	<b>R</b>
Threat status of species	<b>B</b>	<b>S</b>	<b>R</b>
Coral reef ecosystems	<b>B</b>	<b>S</b>	<b>R</b>
Pressure for coastal and marine recreation	<b>B</b>	<b>S</b>	<b>R</b>
Communication services	<b>S</b>		<b>S</b>
Road network	<b>S</b>		<b>S</b>
Employment	<b>S</b>		<b>S</b>
Education completion Rate			
Water resources	<b>B</b>	<b>S</b>	<b>R</b>
Bathing water quality			
Coastal zone litter	<b>B</b>	<b>S</b>	<b>R</b>
Sand quality	<b>R</b>	<b>S</b>	<b>R</b>
Coastal erosion	<b>B</b>	<b>S</b>	<b>R</b>
Sea level rise	<b>B</b>	<b>S</b>	<b>R</b>
Vulnerability to coastal zone hazards	<b>R</b>	<b>S</b>	<b>R</b>



## Indicator 18: Coastal erosion

	Coastal erosion		
	Scenario 1	Scenario 2	Scenario 3
Land use change and degradation	<b>R</b>	<b>S</b>	<b>R</b>
Coastal touristic development	<b>B</b>	<b>S</b>	<b>R</b>
Demand for property on the coast	<b>B</b>	<b>S</b>	<b>R</b>
Population growth rate	<b>B</b>	<b>S</b>	<b>R</b>
Fragmentation of habitat	<b>B</b>	<b>S</b>	<b>R</b>
Threat status of species	<b>B</b>	<b>S</b>	<b>R</b>
Coral reef ecosystems	<b>B</b>	<b>S</b>	<b>R</b>
Pressure for coastal and marine recreation	<b>B</b>	<b>S</b>	<b>R</b>
Communication services	<b>S</b>		<b>S</b>
Road network	<b>S</b>		<b>S</b>
Employment	<b>S</b>		<b>S</b>
Education completion Rate			
Water resources	<b>B</b>	<b>S</b>	<b>B</b>
Bathing water quality	<b>R</b>		<b>B</b>
Coastal zone litter	<b>B</b>	<b>S</b>	<b>B</b>
Sand quality	<b>R</b>	<b>S</b>	<b>B</b>
Marine resources index	<b>R</b>	<b>S</b>	<b>B</b>
Sea level rise	<b>R</b>	<b>S</b>	<b>B</b>
Vulnerability to coastal zone hazards	<b>R</b>	<b>S</b>	<b>R</b>

## Indicator 19: Sea level rise

	Sea level rise		
	Scenario 1	Scenario 2	Scenario 3
Land use change and degradation	<b>R</b>	<b>S</b>	<b>R</b>
Coastal touristic development	<b>B</b>	<b>S</b>	<b>R</b>
Demand for property on the coast	<b>B</b>	<b>S</b>	<b>R</b>
Population growth rate	<b>B</b>	<b>S</b>	<b>R</b>
Fragmentation of habitat	<b>B</b>	<b>S</b>	<b>R</b>
Threat status of species	<b>B</b>	<b>S</b>	<b>R</b>
Coral reef ecosystems	<b>B</b>	<b>S</b>	<b>R</b>
Pressure for coastal and marine recreation	<b>B</b>	<b>S</b>	<b>R</b>
Communication services	<b>S</b>		<b>S</b>
Road network	<b>S</b>		<b>S</b>
Employment	<b>S</b>		<b>S</b>
Education completion Rate			
Water resources	<b>B</b>	<b>S</b>	<b>B</b>
Bathing water quality	<b>R</b>		<b>B</b>
Coastal zone litter	<b>B</b>	<b>S</b>	<b>B</b>
Sand quality	<b>R</b>	<b>S</b>	<b>B</b>
Marine resources index	<b>R</b>	<b>S</b>	<b>B</b>
Coastal erosion	<b>R</b>	<b>S</b>	<b>B</b>
Vulnerability to coastal zone hazards	<b>R</b>	<b>S</b>	<b>R</b>

## Indicator 20: Vulnerability to coastal zone hazards

	Vulnerability to coastal zone hazards		
	Scenario 1	Scenario 2	Scenario 3
Land use change and degradation	<b>R</b>	<b>S</b>	<b>R</b>
Coastal touristic development	<b>B</b>	<b>S</b>	<b>R</b>
Demand for property on the coast	<b>B</b>	<b>S</b>	<b>R</b>
Population growth rate	<b>B</b>	<b>S</b>	<b>R</b>
Fragmentation of habitat	<b>B</b>	<b>S</b>	<b>R</b>
Threat status of species	<b>B</b>	<b>S</b>	<b>R</b>
Coral reef ecosystems	<b>B</b>	<b>S</b>	<b>R</b>
Pressure for coastal and marine recreation	<b>B</b>	<b>S</b>	<b>R</b>
Communication services	<b>S</b>		<b>S</b>
Road network	<b>S</b>		<b>S</b>
Employment	<b>S</b>		<b>S</b>
Education completion Rate			
Water resources	<b>B</b>	<b>S</b>	<b>B</b>
Bathing water quality	<b>R</b>		<b>B</b>
Coastal zone litter	<b>B</b>	<b>S</b>	<b>B</b>
Sand quality	<b>R</b>	<b>S</b>	<b>B</b>
Marine resources index	<b>R</b>	<b>S</b>	<b>B</b>
Coastal erosion	<b>R</b>	<b>S</b>	<b>B</b>
Sea level rise	<b>R</b>	<b>S</b>	<b>R</b>

## 5.0 Conclusion and Recommendation

The project work was specifically on Flic en Flac demo site. Flic en Flac is a touristic village which has known an increase in its level of development within the past years. The identification of coastal zone issues was one of the aims of the study and this was carried out through observation within the demo site. One, the variables were identified, they were classified according to the EU Recommendation which was modified and adapted specifically to Flic en Flac demo site. Available data from relevant stakeholders were collected. However, some data could not be obtained as the stakeholders affirmed that no such collection is carried out. Simultaneously, views from stakeholders which provided the data were sought: they were asked whether a variable is dependent on another one and what are their relationships. These views enabled the development of a systemic model, causal loop diagram which was an illustration of the existing relationship between the variables. This step confirms the second objective of the study: a systems approach may be used to address coastal zone issues. Moreover, based on the opinions of the stakeholders, the coastal zone variables of the Flic en Flac demo site have been ranked using a formula. These variables were ranked according to their importance, i.e. their impact on the coastal zone. Also, the coastal issues were the basis to the identification of indicators specific to the Flic en Flac demo site. Indicators are essential for the evaluation and monitoring of ICZM. 20 indicators and 82 measurements were identified and these are specific for the Flic en Flac demo site. These indicators were then used for scenario analysis. Three scenarios have been described and the effects of one indicator on another have been simulated.

For proper evaluation and monitoring of an ICZM process, there is a need of a proper set of data. However, during data collection, it has been observed that data for certain variables are not collected while certain data have been collected only for the past five or even one year. Missing data is considered as a loophole for proper evaluation and monitoring of ICZM. Hence, there is a need for collaborative actions on behalf of all stakeholders for data collection and eventually for the proper set up of an evaluation and monitoring system.

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