

Developing a framework for an ecosystem-based approach to sustainable marina development

Including a framework application case study for a marina on the island of Mauritius, Indian Ocean



Gosse Gideon de Boer

November, 2016

Cover photo credits: The cover photo is a photo I took of a Vaco Baissac painting during the field trip in Mauritius. I found the painting in my hotel room in the hotel of Les Cocotiers, on the island of Rodrigues. Vaco Baissac (<http://vacoartiste.com>) has painted many paintings like this one, in a series on the Mauritian environment.

The painting integrates sailing boats amid Mauritius' nature and wildlife, representing the integration of a sustainable marina in the Mauritian natural environment. In the top left, the Le Morne Brabant can be seen. An iconic, rugged mountain with a notable link to the abolition of slavery: On February 3rd, 1835, runaway slaves leaped of the mountain in fear of being caught by a governmental search party. This party, however, actually went there to announce the fact that all slaves were freed, and slavery was abolished on the island. The mountain is found in the same area the conceptual marina has been developed in.

Developing a framework for an ecosystem-based approach to sustainable marina development

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by

G.G. de Boer

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Graduating committee:

prof. ir. T. Vellinga	TU Delft; Ports & Waterways
ir. B. Wijdeven	TU Delft; Ports & Waterways
ir. M. de Jong	Royal HaskoningDHV
dr. ir. B. Broekmans	TU Delft; Technology, Policy and Management

Student:

Name:	G.G. de Boer
Student number:	1364022
Date:	16-11-2016
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Summary

This thesis report considers the topic of sustainable marina development. This term can be understood to be a combination of two terms; “sustainable development” and “marina”. Sustainable development in this research study has been considered in relation to the coastal zone and basically entails an approach to ensure a balance between the environment and economic development. A marina, being a coastal (economic) development, interacts with the environmental conditions of the coastal zone and as such, affects the balance for sustainable development. Sustainable marina development is subsequently defined as the development of a marina in such a way and capacity, that the marina integrates its natural, social and economic environment. Additionally, a marina cannot be deemed sustainable by itself, as important principles for sustainable development like the cumulative impacts, multiple (long-term) objectives and sustainability need to be considered on the level of the larger coastal zone, or ecosystem.

Currently, marina design is considered to lack an integrated development approach, and is inadequately represented in current marina development guidelines. Especially the initial stages of marina development, involving important development considerations like location selection and alternatives evaluation, lack the assessment of a marina’s integration in its natural, social and economic environment; a key element of sustainable development.

Framework for sustainable marina development

To be able to achieve sustainable marina development, a framework is developed for the initial stages of marina development, filling the currently observed gap in practical guidance. The framework takes an ecosystem-based management (EBM) approach to development, as the (marine) ecosystem is considered to be at the basis of sustainable development; the linking factor between the environment and development.

From the findings of the literature study, the expressions of EBM and sustainable marina development, together with their principles, resulted in the development of an initial framework for sustainable marina development. An important aspect of the framework is the ecosystem assessment, aimed at assessing the interaction between the marina and its natural environment. For this purpose, the “marina – ecosystem interrelations tool” has been developed. The tool provides a complete insight on the interactions between a marina and its natural environment. This has been done by integrating the concept of Ecosystem Services as a complete representation of the natural environment. The result that the tool generates reveals potential critical points, where the marina and the ecosystem interact. The tool also shows interactions that could prove to be of benefit to the marina, to the ecosystem, or to both.

Aside from the ecosystem assessment, analyses of more relevant aspects (i.e. market, hydrodynamic, regional) are part of the framework. This is the basis of a more integrated approach to marina development. Stakeholder involvement as well, has a prominent place throughout the framework, as integration of functional requirements, societal choice, socio-economic factors and ecological values are key to a successful ecosystem-based management strategy for sustainable development. The understanding obtained from the analyses stage is taken to a location selection and alternatives evaluation. For location selection, the area of interest is subdivided in eco-regions with distinct environmental conditions and setting. These regions are assessed for a set of criteria, among which is the degree of ecosystem integration. For a selected location, alternatives are developed. Together with the 'no marina development' scenario, these are evaluated against each other, based on their ecosystem- and socio-economic integration, stakeholder support, functionality, cost, long-term et cetera. The result of the evaluation is also the product of the framework; a conceptual sustainable marina.

Overarching the framework for sustainable marina development is the ecosystem-based coastal zone management plan, aimed at sustainable development of the coastal zone. It considers aforementioned elements of sustainable development like the cumulative impacts, multi (long-term) objectives and sustainability on the scale of the coastal zone, or ecosystem. The coastal zone management plan is linked with monitoring strategies, as well as the licensing procedures, to be continuously able to adapt to changes in the environment, context or developments. The latter is also a key element of sustainable development.

Case study Mauritius

The developed framework has been applied to the case of Mauritius. Mauritius offers an interesting context as the natural environment around the island is of high environmental value, providing a large range of services to the people and industries of Mauritius. The environment is very sensitive as well, ecosystem degradation and loss of Ecosystem Services has been identified around the island. In terms of marinas, the island has known very little development. Although boating conditions are excellent and the marina business could benefit the island's economy, only one small public marina has been realized. It appears that part of the reason for the absence of marinas in Mauritius is the island's coastal zone management policy. Strict regulations apply for coastal zone development, guided by an Integrated Coastal Zone Management (ICZM) strategy. Various marina proposals have failed to obtain an Environmental Impact Assessment (EIA) licence, indicating an unacceptable impact on the natural environment.

When comparing the initial framework for sustainable marina development with the Mauritian ICZM strategy, it is concluded that the ICZM strategy falls short in considering the integration of

developments in its environment. This is a critical element for sustainable development. Further, guidelines to marina development are not advanced and offer no guidance to sustainable marina development. Therefore there is a clear need for the application of the framework in Mauritius. It is also concluded that an EBM approach to sustainable marina development appears to be better suited than the ICZM approach.

From the application of the initial framework to the case study, several enhancements to the framework are developed and assessed. To be able to apply the enhanced framework, an EBM strategy for the island has been assumed, to provide the basis for sustainable development. This has been done by applying the set of EBM principles throughout the framework, and integrating the coastal zone management plan in the framework.

Results

An important step of the framework, the ecosystem assessment, has been executed by applying the marina – ecosystem interrelations tool to the given area of interest. The tool performed well and provided valuable insight on the opportunities for integration of a marina in different ecosystems in the area of interest. This provided guidance on location selection, as well as alternatives evaluation and carries information for subsequent design, construction and operation stages.

By applying the framework, the preferred location could be selected. With the location decided, a conceptual design for a sustainable marina has been developed for that location. The location, design and incorporation of socio-economic aspects in the area have merged into a concept for a sustainable marina that is integrated in its natural environment, as well as in its social- and economic environment. Also, by having assessed the national visions for tourism, environment and economy, the marina could be a welcomed development in the area.

Concluding, the framework for sustainable marina development is shown to be effective in providing the practical guidance needed in the initial development stages. The tool for an ecosystem assessment – the marina – ecosystem interrelations tool – provides the insight needed for a reliable judgement on ecosystem integration, location selection and alternatives evaluation.

Additional research is recommended to focus on the link between the framework and subsequent stages of marina development, taking the insight obtained on the marina's integration in its environment forward to design, construction and operation stages.

Preface

This research study has embodied a selection of personal interests and has driven my passion for the subject of sustainable marina development. The subject of marina development has by no means been a random choice. Although marina development is not overly represented during the Hydraulic Engineering programme, it is an integral part in the field of Ports of Waterways engineering, and perhaps the lack of representation has signalled the need for additional research. When prof. ir. T. Vellinga suggested the subject, I was struck by the obvious. With my elaborate sailing endeavours, implied experience with marinas and personal passion for the sea, the waterfront and their interaction, the subject was perfect.

In a subsequent meeting with ir. B. Wijdeven and ir. M. de Jong, I also expressed the wish to graduate under the umbrella of Royal HaskoningDHV, participating in an ongoing project. The wish was granted later when an ongoing master plan study for Port Louis, Mauritius included a marina development study, starting at the same time as I wanted to start my graduation process.

Being spoilt by such an opportunity I set to work, and the case of Mauritius immediately became a very interesting one. The visit has driven the research study in a sustainable marina development direction, where the integration of a marina in its natural, social and economic environment is critical to come to marina realization and to sustainable development of the coastal zone.

Although Mauritius has an incredible potential for marina development, public marinas barely exist. Regardless, I found the opportunity to sail along the coasts in a sailing race with the Black Dog racing team. An amazing trip with great sailors; I thank them for having me on board and around, and hope to re-join the team soon!

I would like to thank aforementioned persons Tiedo, Bas and Michiel as well, as they offered me the opportunity to graduate on the subject that is closely linked to my personal interests, by forming the graduation committee. In addition, I owe my thanks for the completing member of my graduating committee, dr. ir. B. Broekhans (Bertien). At several times in the past months, she has distinguished herself from the committee with feedback from her expertise, and on the scientific level.

There are many more people to thank in relation to my thesis completion, and even more to thank for the completion of my education at the Delft University of Technology. It's been a ride!

Thanks reader, for reading at least this page, and enjoy reading the remainder of the thesis!

Gosse de Boer,
November 15th, Amersfoort

List of abbreviations

BOI	Board of Investment (Mauritius)
CBCM	Community-based coastal management
CEG	Civil Engineering and Geosciences
CMM	Certified Marina Manager
DUT / TUD	Delft University of Technology
EBM	Ecosystem-based management
ECTS	European Credit Transfer and accumulation System
EIA	Environmental Impact Assessment
EPA (2002)	Environmental Protection Act 2002
ES	Ecosystem Services
ICZM	Integrated Coastal Zone Management
MARE	Marine Affairs Research and Education
MEA	Millennium Ecosystem Assessment
MEAM	Marine Ecosystems and Management
MCES	Marine and Coastal Ecosystem Services
MSc	Master of Science
MoE	Ministry of Environment (Mauritius)
NMMA	National and Marine Manufacturers Association (USA)
NOAA	National Oceanic and Atmospheric Administration (USA)
PER	Preliminary Environment Report
PIANC	Permanent International Association of Navigation Congresses
RHDHV	Royal HaskoningDHV
SEA	Strategic Environmental Assessment
TEEB	The Economics of Ecosystems and Bio-diversity
TPM	Technology, Policy and Management
TYHA	The Yacht Harbour Association
UNEP	United Nations Environment Programme
WCED	The World Commission on Environment and Development
WWF	World Wildlife Fund

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Part 0. Research Introduction: A framework for sustainable marina development

In this Part, the challenge to get to sustainable marina development is expressed. In the first chapter, Chapter 0, the problem is stated. It delivers the motivation for research, but it also gives rise to the question 'what *is* sustainable marina development?' In the next chapter, Chapter 2, this is being elaborated.

As any marina has a part in its marine environment by definition, the surrounding coastal zone and the marina interact with each other. From Section 2.3, this link is shown to be of large importance to sustainable marina development. The way coastal zones are managed is critical in achieving a sustainable marina. Therefore, in the last chapter of Part 0, Chapter 3, different coastal zone management approaches are introduced and evaluated. One approach, ecosystem-based management, is shown to be preferred in achieving a sustainable coastal zone. The link between ecosystem-based management and sustainable development is given in Section 3.3.

1. Research introduction

To introduce the research, the problem and findings that spiked interest towards the subject of sustainable marina development is elaborated in the first section. Consequently, research objectives are set out in Section 1.2. A research question is posed, and a method is formulated to find an answer to the research question in Section 1.4.

1.1 Problem statement: Unsustainable, unguided marina development

This MSc research report is aimed at developing a framework for a present-day approach to marina development and presenting an example of the principle, by applying – and enhancing – the framework in a case study for the island of Mauritius. The scientific motivation for this research is twofold;

Firstly, there is a need for change in current coastal development practice (Halpern *et al.*, 2008). With growing populations in coastal areas, the coastal environment is struggling – and often suffering – to keep up with the increased demand populations pose on their environment (Millenium Ecosystem Assessment, 2005). Marina development, a coastal development, inevitably contributes to the increased pressure on the environment. Paragraph 1.1.1 discusses the role current marina development practice has in a coastal zone.

Secondly, existing guidelines to marina development are inadequate. There is a lack of guidance concerning the first phases of marina development, and there is insufficient regard to achieving a sustainable marina. Current guidelines are wide-spread across the world and are often outdated. PIANC working group 149 has recently [August, 2016] made a collection of guidelines, aiming at producing a single guideline, generically applicable for marina development (PIANC WG149, 2016). Paragraph 1.1.2 elaborates on the current supply and state of marina development guidelines and supports the proclaimed problem of guideline deficiency.

An extra boost to the urge to conduct research has been a trip to the island of Mauritius in the Indian Ocean. On this island, there is an incredible opportunity to marina development, according to a national development agency, the Board of Investment (BOI, 2013). Its tourism development, tropical climate, and marine environment are named as important assets towards the goal of marina development. Also, from an author's perception, the island indeed offers great opportunities for a boating scene, and associated marina development. First-hand experience, however, shows very little marina development around the island, and subsequent very little boating. There are multiple reasons for this, but one notable reason has become clear from investigation; environmental regulations and licensing (Ministry of Environment, 2016). Numerous marina proposals have stranded at the Ministry of Environment, through no granting of a license. Paragraph 1.1.3 provides a

more detailed insight on the Mauritian marina case. A framework for sustainable marina development could prove very valuable for a marina development in Mauritius, as a sustainable marina would have to be integrated in its natural environment, see Chapter 2.3.

By developing a framework for sustainable marina development, aimed at the first development stages, the lack of a guideline for this phase can be solved. The framework will embody a change in current practice for marina development, and contribute to sustainable development of the coastal zone.

1.1.1 Unsustainable coastal development

Coastal developments of all sorts (i.e. resorts, beaches, ports, storm defences) have grown in number over the last decades, driven by economic and technological growth and the increase of the earth's population, concentrating around coastal areas (de Vriend *et al.*, 2015; Waterman, 2010). These communities depend on the coastal zone for food, energy, health, recreation et cetera, through the services the coastal zone provides. In literature, scientists and policy experts concur in the fact that the way coastal zones have been managed in the past is not sustainable (Halpern *et al.*, 2008; van Eeten *et al.*, 2002). Reasons for this are found relations between coastal development, their associated anthropogenic impacts, and declining ecosystem health. The latter is expressed by monitored reductions of biodiversity, declining water quality, aesthetics, declining fish catches and much more, at a global scale. These effects have a direct impact on the community that the coastal zone can (in)directly support in terms of for example food, health and life quality. The continued demand is likely to create resource compression and supply chain constriction (Matlock *et al.*, 2011). (Scheffer *et al.*, 2001) nuances this statement by stating that services are depleted, by human's aim to maximise return of certain services. For example, a fishery area may look to maximise fish catches, but may cripple the underlying services that support fish populations. These underlying services may also be hampered to deliver other services like air-/ water purification (seagrasses, mangroves) or coastal protection (coral reefs).

To be sustainable, a coastal zone will need to be able to deliver its goods and services for this generation, as well as for future organizations (Millenium Ecosystem Assessment, 2005; UN Sustainable Development, 2016). As this is not the case at the moment, a change is needed in the way coastal developments are approached (de Vriend *et al.*, 2015). According to (Ruckelshaus *et al.*, 2008; Sorensen, 1997), a better approach would need an integrated, system-wide, participatory and adaptive approach, that takes into account the full array of interactions within an ecosystem, including human uses. These characteristics of an approach are supported by (Matlock *et al.*, 2011). What these notions exactly mean, and how sustainable development can be defined is elaborated on in Section 2.1.

This paragraph has presented literature that considers coastal development. It is important for this report to state the place marina development has in this scheme. A definition of a marina is given in Section 2.2, but at this point, it is enough to realize that a marina is an example of a coastal development. It also has an impact on its social, economic and natural environment and hence, the coastal zone. Although a marina only has a part in the total of anthropogenic impacts in a coastal zone, it surely contributes. Over time, different parties have indicated the impact marinas and marina operations have on their environment (Epsilon Associates Inc, 2001; McAllister *et al.*, 1996; McPherson *et al.*, 2014; Neil Ross Consultants, 1996; PIANC WG12, 2002; PIANC WG98, 2008). Impact of marinas occurs by a range of effects, like destruction of habitat, hampering of natural flows in the area, human presences and pollution.

1.1.2 Marina development guidelines

Until very recently [August, 2016], the current supply and state of guidelines has been rather spread out across the world with the larger, more developed, coastal nations each having their own guideline on how marinas should be designed and operated. In August, 2016, PIANC has published a guideline on marina design, based on all available guidelines (PIANC WG149, 2016). Although marina guidelines have been spread out around the globe, the country-specific and the PIANC guideline largely concur in the guidance on marina layout, required facilities and design considerations.

Also, a certain amount of environmental awareness is shown in choice of materials, prevention of pollution, sewage and drainage systems and fuelling procedures (Epsilon Associates Inc, 2001; McPherson *et al.*, 2014; Standards Australia International, 2001).

For any engineering project, there are different development stages. Starting with the very idea of a marina, the idea develops to a preliminary design after feasibility studies for a certain location and subsequently, design detailing. After licensing and construction, the marina will be operated and marina users will use the facilities and undertake marine activities. Ultimately, the marina reaches an end of lifetime. The existing set of guidelines for marina design is applicable to only a certain time period of the design, as only those development choices are guided. The following figure depicts the marina development timeline.

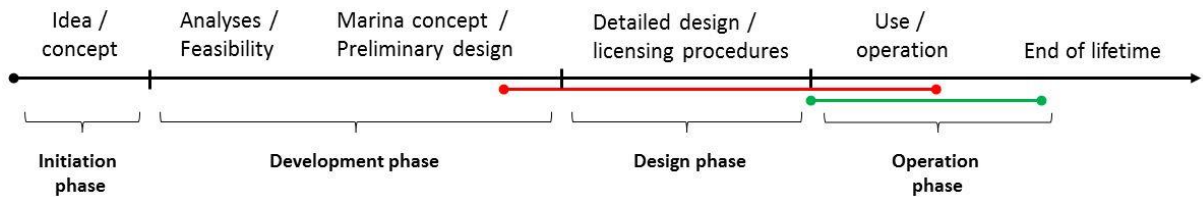


Figure 1 - Marina development stages, adopted from (Baars *et al.*, 2015)

In Figure 1, two development periods have been indicated. The red-coloured period, refers to the period where current guidelines apply, as discussed above. The green-coloured period, refers to the period where the marina is in use and operating. For this period, several countries (notably the U.S.A, E.U. and Australia) have produced several initiatives to promote stewardship. A selection of these initiatives is aiming for the marina users category and promotes awareness on the use of their yachts, their waste and their impact on the environment. Good examples are the 'Good mate program' (McPherson et al., 2014), the 'NMMA Water watch program' and the 'Tread lightly campaign' (Fontaine et al., 2008), amongst others. Accomplished initiatives aiming for stewardship on the marina operation side are the 'Clean Marina Program', or 'Blue Flag Program' and the 'Certified Marina Manager (CMM) program' (Fontaine et al., 2008). Another wide-spread accreditation scheme, aimed at providing a customer focused framework for marinas, is the 'Gold Anchor International Rating Scheme for Marinas', of the Marina Industries Association (MIA) and The Yacht Harbour Association (TYHA) (See Figure 2). Broadly supported, implementation of these initiatives and programs is high on many marinas' agendas (Marina developers interviews), and flags are hoisted at many marinas, see Figure 3.



Figure 2 - Selection of different marina management initiatives, source: Google Images



Figure 3 - Selection of photos taken during sailing events of the author, from left to right; Porto Ercole, Italy; Porto Venere, Italy; Monnickendam, Then Netherlands. (Photo courtesy: Gosse de Boer)

For the development phase however, no guidelines are currently available. Although a guideline is not required by law or other institution, it may assist the process by increasing efficiency and by

placing focus on the more important decisions in marina development. Guidelines are a means of knowledge sharing, so best practices and lessons learned can be shared and adopted in other marina developments.

Summarizing, a marina development has been earmarked as an example of coastal development, and has an impact on the environment through different phases in its project cycle; the development process (site location, context integration), design (configuration, material use), operations (nutrients, chemicals, waste) and its users (waste, movements, human presence). Guidelines exist and are in development for the latter three (design, operations and marina users), but not for the first category of marina development.

Additionally, in relation to *sustainable* marina development, the marina has to be regarded as an integral part of a coastal zone. In many parts of the world, a coastal zone management plan guides coastal development, to ensure sustainable development of the coastal zone (Arkema *et al.*, 2006; Cicin-Sain, 1993; Waterman, 2010). Because, marinas impact the coastal zone, a marina development has to be taken into account by coastal zone management. In Chapter 2, it is shown that for sustainable development of a coastal zone, a marina will need to be guided by guidelines that aim to integrate the marina in its environment, and the system as a whole.

In that sense, a marina development can only be called sustainable, if it fits in with the larger coastal zone, or system, which is managed for sustainable development. Guidelines integrating a system level sustainable development approach are non-existent at this point in time.

Concluding this paragraph, one can see that the existing set of guidelines does not suffice in achieving a sustainable marina (a marina in a sustainable coastal zone); there is a lack of guidance in 1) achieving sustainability and 2) in the early development stages of a marina development.

1.1.3 Marina case Mauritius

In light of the research study, a field trip has been undertaken to the island of Mauritius in the Indian Ocean. Here, a project team of Royal HaskoningDHV was consulting the Mauritius Ports Authority on the master plan for the commercial port of Port Louis. Part of the project brief was to have an initial assessment of potential marina development around Mauritius. Over the course of six weeks, information has been obtained on the marina context in Mauritius; the coastal environment, the market potential for a marina and the question why only little marine facilities are present in Mauritius.

In Chapter 0, of Part III, a more detailed elaboration of the case for Mauritius has been presented. Here, the reason why the field trip to Mauritius has provided an urge to conduct research on sustainable marina development is given.

There are very little marina facilities around Mauritius. There is one public marina with room for twenty boats and very limited facilities, in the middle of the commercial port of Port Louis. Additionally, there are scattered single piers and/or floating docks in naturally sheltered areas, and there is a newly developed residential marina, called La Balise. This marina however does not have a public marina function.

This amount of marina facilities is very little, and especially in comparison to other locations in the region. For example, the island of Réunion, knows over a dozen marinas, and a lively boating scene. The archipelago of the Seychelles, at a distance, knows an ever bigger boating scene and an uncountable number of marinas, providing 15% of the country's GDP (WTTC, 2015).

Although the island of Réunion and the Seychelles offer different coastlines, sailing conditions are among the best in the world. Without a doubt, supported by first-hand experience and national brochures on marina investment, Mauritius offers magnificent sailing conditions.

There are numerous reasons for the lack of marinas around Mauritius. The political standpoint, the current lack of boating, strict regulation of coastal developments and a sensitive marine environment are known reasons. The latter two have caused a selection of marina proposals to strand at the EIA licensing stage (Ministry of Environment, 2016). In an interview with the Ministry of Environment in October, 2015 the notion was confirmed that environmental impact assessment reports of marinas are 'not good enough' and did not suffice to meet the required standards set out by the Ministry.

Unfortunately, the Ministry's responses to the EIA reports are not public and could not be accessed. Nevertheless, the EIA license is a clear challenge for marina proposals, one that has ended past projects.

The Mauritian coastal environment indeed is very sensitive, with coral reefs, lagoons, mangroves, sea grasses, endemic species and a large pressure from coastal developments (pollution, trampling, and fishing). The coastal environment poses challenging conditions for a marina development.

The purpose of this research study is to develop a framework for sustainable marina development, which is generically applicable at any location. The island of Mauritius provides an interesting location for a case study of the framework, as there is large potential for marina development, as well as a need for sustainable development. By applying the framework for the case of Mauritius, insight can be gained on what important considerations are for a marina in Mauritius. To be a sustainable marina, the marina will have to be well integrated in the context of the island, in an ecological, societal and economic sense. A better integration of a marina in the natural environment would benefit the EIA licensing stage.

1.2 Research objectives

The foremost objective is to deliver a framework for sustainable marina development. With the framework, a first step can be taken to solve the problem of unsustainable, unguided marina development. To incorporate present-day views and sustainability goals, the ecosystem-based management approach will be the basis of this, as will be reasoned in Chapter 3. Through a case study for a marina development in Mauritius, the framework will be enhanced.

To organize the thesis, the report has been split up in different parts. Each part deals with a part of the research and is driven by the respective research objective. The framework and literature background will be captured in Part 0 and I. Part II entails a comparison study to evaluate differences in approach of the initial framework and existing practice in Mauritius. The fourth part (Part III) entails a case study, where the framework is applied for a marina development in Mauritius. This process may enhance the framework and deliver a preliminary proposal for a sustainable marina in Mauritius. Part IV concludes the research study by listing the main conclusions and recommendations.

Below, an overview of the report setup is given, indicating the main research objectives per Part.

Part 0. Research introduction – In this part the objective is to understand the problem and to give start to a research study. An understanding needs to be obtained on the concept of a sustainable marina development and coastal zone management.



Part 0

Part I. Developing the framework – Based on information from Part 0, a framework can be formulated for sustainable marina development. An ecosystem-based development approach is taken in the framework, implying that an understanding of the marina – ecosystem interrelation is required.



Part I

Part II. Framework comparison – Understand what differences and similarities are present between the current Mauritian coastal zone management and the initial framework. This may deliver insight on sustainable marina development, and the added value the initial framework may have.



Part II

Part III. Case study Mauritius – Preliminary sustainable marina design, framework enhancement;



Part III

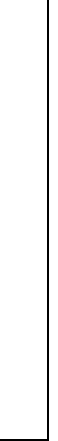
Part IV. Conclusion – Conclusions and recommendations.



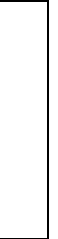
Part IV

Next, an overview is given of the sub-objectives per Part. Numbering corresponds to numbering of research method steps, given in Section 1.4.

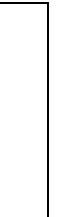
- 1. Achieve an understanding of the problem considered; assess the existing global marina development field.
- 2. Collect information about marina development in Mauritius;
- 3. Link marina development to the coastal zone management. Define sustainable marina development, ecosystem-based coastal zone management.
- 4. Formulate a Problem Statement and research challenge, with research objectives, question and method.
- 5. Define boundary conditions for the sustainable marina development framework.
- 6. Integrate an ecosystem-based approach to marina development;
- 7. Formulate an initial framework for sustainable marina development.
- 8. Map existing coastal zone management for Mauritius, with special regard to marina development/design.
- 9. Evaluate the framework from Part I, in relation to the existing coastal zone management and marina development framework of Mauritius.
- 10. Understand the economic, social and environmental context of Mauritius with regard to marina development. Provide general information for a case study.
- 11. Apply the framework in a case study. The area of interest will be Mauritius. Develop a preliminary sustainable marina design.
- 12. Enhance the framework, evaluate the framework.
- 13. Evaluate the merit achieved.
- 14. Formulate conclusions and recommendations.



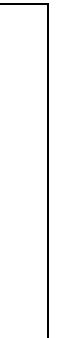
Part 0



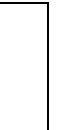
Part I



Part II



Part III



Part IV

1.3 Research question

To achieve the set objectives, a main research question is formulated as follows;

'How can a framework be formulated to guide the initial stages of marina development, in order to achieve a sustainable marina, being a marina that is an integral part of a sustainable coastal zone through ecosystem-based management?'

To answer the main research questions, the following sub-questions are formulated;

Sub-question 1: *'What is a sustainable marina?'*

Sub-question 2: *'How should a coastal zone be managed to be able to achieve a sustainable coastal zone?'*

Sub-question 3: *'At which stages of marina development can a framework for sustainable marina development provide support towards the goal of a sustainable marina?'*

Sub-question 4: *'Could the framework develop a conceptual design for a sustainable marina for the island of Mauritius?'*

1.4 Research method

Per sub-objective, a method can be used to reach that objective, and is subsequently used to contribute to answering the research question. The numbered methodology steps below follow the numbering of research objectives above.

1. Literature study; to get an idea of the problem, current practice needs to be assessed. This is done through analysing the current set of guidelines to marina development, as well as achieving an idea about *sustainable development in relation to marinas* from literature.
2. A) Field trip; Assess the marina development situation in Mauritius. Collect all relevant information about coastal and marina development, like coastal characteristics, socio-economics, political environment, marine ecosystems et cetera. Information on existing marina developments/proposals, and local guidelines, should be obtained.
B) Interviews; Meet and interview stakeholders and people involved with marina development.
3. A) Literature study; From literature, find an articulation of sustainable development for marinas, and describe the role a marina plays within a coastal zone.
B) Literature study; Assess current strategies for coastal zone management approaches. Link marina development to coastal zone management.
4. Conclusion; Concluding steps 1 through 3, formulate research objectives, a research question and a method to reach the research objectives.
5. Framework development; Based on previous findings, boundary conditions for a framework can be given. Also main points of the framework should consider are named.
6. Framework development; A tool needs to be developed to assess a marina's sustainable integration in its natural environment. This is an important aspect for an ecosystem-based approach, as elaborated in Part 0. Other assessment, like a marinas socio-economic integration and governance are integrated in the framework in step 7.
7. Framework development; Combining the studied literature and insights obtained from the marina industry, an initial framework for sustainable marina development can be formulated.

Part 0

Part I

8. Assessment; Based on research from the field trip (step 3A) and the stakeholder interviews (step 3B), an overview of the existing coastal zone management of Mauritius is created.
9. A) Comparison; Identify differences between the Mauritian framework and the initial framework produced in Part I, step 7.
B) Evaluation; Draw conclusions from the framework comparison. Apparent strengths and weaknesses of each framework can be used to improve the initial framework, and show its added value compared to current practice in Mauritius.
10. Provide base-line information to start the framework from; Describe general information about Mauritius that is applicable to marina development; coastal characteristics, socio-economic aspects, national development strategies, hydrodynamics around Mauritius and an overview of ecosystems present around Mauritius.
11. Apply the initial framework; Execute the steps and phases as the framework has been described. Perform analyses, ecosystem assessments, location selection and alternative selection. Conclude with a preliminary sustainable marina design.
12. A) Evaluation; Based on lessons learned during framework application (step 11) and framework comparison (step 9A,B), the framework can be enhanced.
B) Conclusion; Report the enhanced framework.
13. Evaluation; Based on conclusions drawn from the framework comparison (Part II) and framework application (Part III), the merit that is achieved by the enhanced framework compared to current marina development practice can be named.
B) Conclusion; Provide a reflection on the research study objectives, answer the research question.
14. Recommendations; Provide recommendations for future research on the subject. Give insight on assumptions and uncertainties met during the research study.

Part II

Part III

Part IV

Following the steps of the methodology above, each step's results will give motivation to the next. Ultimately, the objectives are met and the research question can be answered in a discussion following the results. The findings will be elaborated in a conclusion, supplemented by recommendations to allow improvement of the framework in the future.

2. Sustainable marina development

In Chapter 0, the problem of unsustainable development has been stated. The notion of world-wide unsustainable coastal development is widely acknowledged by scientists, policy experts and governments. Major conferences on sustainable development (the UNCED, 1992; the World Summit on Sustainable Development; 2002 and the Rio+20, 2012), cooperation agreements (Agenda 21, Agenda 30) and organizations (for example: United Nations, UNESCO and the International Institute for Sustainable Development) seek to set out a path to sustainable development, to ensure that current and future generations can continue working and living equally.

For sustainability, one needs sustainable development. A definition of either, sustainability or sustainable development, is hard to express. Many variations exist in literature. An expression for sustainable development is given in Section 2.1. This section also provides a list of key principles of sustainable development.

Section 2.2 presents a definition of a marina, as it will be adopted in this research study. It describes functions and services of a marina.

The last section of this chapter combines the two and delivers an articulation of sustainable marina development, which is the subject of this research study. A key element will be explained, being that a marina cannot be called sustainable on its own. A marina can only be sustainable when it fits in a sustainable coastal zone management plan. The main reason for this is that not only the impact of a marina on its environment should be taken into account, but the cumulative impact of all coastal developments and anthropogenic impacts on the coastal zone needs to be considered. The principle of cumulative impacts is a key principle of sustainable development. This and other principles of sustainable development are ensured by the overarching coastal zone management plan, as elaborated in this chapter.

2.1 Sustainable development

Sustainable development is hard to express, as many definitions exist in literature. The most frequently quoted from 'Our Common Future', also known as the Brundtland Report:

Sustainable development: *"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs"*.

Although somewhat vague, this concept of sustainable development aims to maintain economic advancement (i.e. coastal development) and progress while protecting the long-term value of the environment (United Nations, 2015). Effectively, the main goal of sustainable development is to achieve long-term stability of the economy and environment. Aside, from the main goal stated in the brief, United Nations has published the 'Sustainable Development Goals', as a part of Agenda 30. According to the brief of the UN, these goals are only achievable through the integration and acknowledgement of economic, environmental, and social concerns throughout the decision making process. (Matlock *et al.*, 2011) state in their book on ecological engineering, that a less vague definition of sustainable development would limit its scope on sustainability, as sustainability has to consider all elements together, as a whole. Matlock agrees with the statement of United Nations that integration of all disciplines is needed to reach sustainable development. Another addition to the definition of Brundtland is given by (Cicin-Sain, 1993), stating that achieving sustainable development entails a *continuous* process of decision making. And hence, that there never is an 'end-state' of sustainable development, since the equilibrium between development and environment must constantly be adjusted. This addition is widely accepted in literature and therefore included in the listing below.

To summarize the brief of United Nations, that has assessed numerous publications on sustainable development, including reports on the world conferences on sustainable development, the following principles are the main concepts for sustainable development. The last principle, of adaptability is added by the addition of Cicin-Sain.

- Integration of environmental, social and economic concerns into all aspects of decision making.

This principle is the key principle for sustainable development; it implies a multi-disciplinary approach, cross-sectoral management, management of multiple objectives, stakeholder participation and integrality.

- Intergenerational equity.

This reflects a part of the sustainable development definition of the Brundtland report about current and future generations.

- Precautionary principle.

This principle states that where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measure to prevent environmental degradation.

- Interdependency principle.

This principle acknowledges the interdependence between environment and development, as well as the interdependence between elements of an ecosystem, and elements in, for example, a coastal zone.

- Principle of adaptability.

As sustainable development never reaches an 'end-state', and the equilibrium continuously needs to be adjusted, adaptability and continued learning are required.

For the coastal zone, the marine ecosystem has to be considered, as well as the continuous development in coastal areas around the world. As many elements come together in coastal areas; marine ecosystems, terrestrial ecosystems, tourism, transport, urban areas, among many others, the challenge for sustainable development requires complex integration of concerns mentioned above.

2.2 Marinas

A marina is an American (but globally adopted) word for a marine infrastructure meant to harbour yachts and small boats, mostly aimed at pleasure, recreation and leisure use. Its definition varies across a multitude of platforms and a complete definition is not found in literature. However, based on the collection of definition varieties, examples in practice, the following can be stated and will be used in the report, keeping in mind that large variation exists;

Marina: *“A marina is a waterside facility that is specifically designed to harbour (small) pleasure craft. A marina incorporates features for nautical as well as land-side infrastructure, shelter, recreation and commercial development.”*

Depending on the area and environment, a marina will vary in size, type and interpretation of the aforementioned definition. There are a couple of recurring, and essential subjects to a marina development. First and foremost, the navigational access to one or more water bodies. This can be the ocean, sea, estuary, river or lake. It should be safe, navigable and preferably connected to a broader region. Secondly, the shelter a marina provides to its customers against wind, waves and current action. Secondary shelter against theft or malevolence is not part of this essential subject of marina development. The third essential subject is the client and the potential customers. Very often, a marina is pleasure related, making a marina development aiming to provide an ambience for pleasant staying and pleasant boating in the area. The client may have ambitions in regard to a combined development of marina, housing and/or real estate.

To achieve a marina’s goals, it provides the infrastructure, facilities and services accordingly. For example, to achieve a safe and navigable marina, dredging and structural works may be required. Another example can be water quality in the marina and boating area. A good water quality contributes to a pleasant experience for marina customers, directly through its aesthetics and clean appearance and indirectly through the positive impact clean water has on marine ecology (Lipton, 2004).

For assessment in the framework, the following break-down of a marina will be used, representing all elements of a marina and of marina use. Appendix A holds an elaboration of below elements.

Marina elements

- Structural elements
(quay walls, fixed jetties, breakwaters)
- Floating elements
(floating breakwaters, pontoons, docks)

Marina use elements

- Boat presence
(moored boats, engines, boat wastes)
- Onshore activities
(noise, run-off, sewage, nutrients)

- (Maintenance) dredging (of marina basin and navigation channel)
- Bottom structures (piling, anchoring, navigation marks)
- Construction works & maintenance
- Social- / Community places (yacht club, educational centre)
- Marine activities (boating, tour operating, fishing, diving)

The marina elements and marina use interact with its environment. Environmentally, the choice of the marina location, its configuration of sea walls, docks and/or breakwaters, its construction and the use of materials and equipment will all have an impact, as confirmed by nearly all guidelines on marina development. Use of a marina, and marina operations, may also impact the environment by pollution, release of excess nutrients, boating et cetera.

These impacts however, are not the only impacts that are affected on the natural environment. Other developments and anthropogenic actions may also impact the environment in similar, and other ways. Pollution of the coastal zone for example, is not only induced by a marina, but also by guests of hotels in the area, a bad storm water drainage system, an open sewage channel or by commercial vessels visiting the area to enter a port.

A marina therefore must be seen as a part of a larger system¹, one that on a system level needs to be considered for sustainable development. On the system level, several key elements of sustainable development can be safeguarded, like the control of cumulative impacts (the collective of impacts, like the pollution example), but also the integration of different developments and environmental protection in that coastal zone (multiple objectives) and ultimately, the safeguarding of sustainable development. These principles come forward from the key principles of sustainable development in Section 2.1.

The marina development will have to adhere to coastal zone management policy, so that on a system level, all impacts and developments are charted. To be able to fit in with this coastal zone management policy, the marina itself will have to integrate with its natural, social and economic environment. In the next section, an articulation is given for sustainable marina development.

¹ The system refers to the coastal zone considered. For this research study, this has been translated to ecosystems. In this context, system = coastal zone = ecosystem.

2.3 Sustainable marina development

Marina development, including the construction, its presence and its use over time, will have an impact on the environment (McAllister *et al.*, 1996; McPherson *et al.*, 2014; PIANC, 1979; PIANC WG12, 2002). Marinas are, by its function, built in the vicinity of a waterbody. A large, but unknown number of marinas has been realised in coastal areas. The prognosis is that this sector will continue to grow in the future, with special attention to (sub) tropical locations and locations with large nature-based tourism potential. Contributing to this prognosis is an article of (Balmford *et al.*, 2009), confirming a rise in nature-based tourism in over 15 countries, located mostly in (sub)tropical zones.

There is no definition of sustainable marina development in literature. However, the term of sustainability in relation to marinas is mentioned in several pieces of literature and news articles, usually with respect to exhibited aquatic stewardship, sensible operation of marinas and responsible behaviour of its users (Fontaine *et al.*, 2008; McPherson *et al.*, 2014). Although contributing to sustainability, a marina development cannot be concluded to be sustainable solely by application of these principles.

This notion refers to the stages of marina development. Environmentally sound operation of marinas, environmental stewardship and responsible behaviour of users are part of the green-coloured phase in Figure 1. A proper sustainable marina development considers the entire marina development process as introduced in the previous section, from initiation to the operation and use phase and ultimately, its entire lifetime. Also, it needs to consider its role in the coastal zone, being managed by coastal zone management plan.

To formulate an articulation of sustainable marina development, a statement of the United Nations for sustainability in the coastal zone is adapted (UNEP, 1995). Also, the philosophy of the integrated approach to coastal zone management has been incorporated;

Sustainable marina development: *“The development of a marina in a location, capacity and way that is consistent with a sustainable coastal zone development plan, making use of components of the environment in a way and at a rate that contributes to natural biodiversity, ecosystem functioning and the ability to provide Ecosystem Services, for current and future generations, incorporating all interrelations between environmental, social and economic values constituting and/or affecting the ecosystem.”*

The following elements are brought forward in this articulation, which are briefly highlighted below.

‘Development’; this notion refers to the specific development phase, in the total project cycle of a marina (see Figure 1).

‘Location, capacity and way’; the consideration of a location, is a critical feature in sustainable marina as the location affects its place in the marine ecosystem, as well as its place socio-economically. Location selection

‘Consistent with a sustainable coastal zone development plan’; this part will be explained in the next chapter, Chapter 3, of this report. In short, by including this, certain goals are achieved like the managing of multiple objectives, cumulative impacts and sustainability. These are goals that are consistent with the 6 key elements of the ecosystem-based management approach of a coastal zone, identified in Section 3.2.

‘Surrounding region’; the region is not limited to the marina’s local area, but includes the coastal zone. This coastal zone considered is based on ecosystem boundaries, and to a certain degree, political or economic borders. For the remainder of this report, the considered region will be defined as ‘eco-region’.

‘Earth’s resources (Ecosystem Services)’; the principle of Ecosystem Services is explained in the following part of the report. In short, these are the benefits (both tangible and non-tangible) people derive from ecosystems. To incorporate marina development in an ecosystem-based coastal zone management plan, the interrelation between a marina and its environmental context is illustrated by Ecosystem Services.

‘For current and future generations’; this represents an essential part of sustainability and sustainable development, as introduced in the Section 2.1, with the principle of ‘intergenerational equity’. It implies that the marina development and coastal zone management will have to achieve and maintain a balance in economic, social and environmental context.

In this articulation, and description of its elements, the ecosystem comes forward multiple times. As will be elaborated in the subsequent chapter, the ecosystem is actually at the basis of sustainable management of the coastal zone. So-called ecosystem-based management will be shown to be the most adequate way for sustainable development of the coastal zone.

3. Coastal zone management

In previous chapters, coastal zone management has come forward. In the problem statement, the finding that current coastal zone management is considered unsustainable across the world, has been backed up with the international conferences on the subject, advocating a paradigm shift in the way sustainable development of the coastal zone is being organized. This is being acknowledged by a large number of research studies and publications (Cicin-Sain, 1993; Cicin-Sain *et al.*, 1998; Clark, 1992; de Vriend *et al.*, 2015; S. A. Levin *et al.*, 2008; Sorensen, 1997; Waterman, 2010).

A statement shared by all, is the need for *integrated* coastal zone management, clearly linking to the main principle of sustainable development; integration of environmental, social and economic concerns into all aspects of decision making.

Over the course of time, different ways of integrated coastal zone management have been developed and introduced. Three main approaches are evaluated in Section 3.1, after which ecosystem-based management of the coastal zone is deemed most appropriate for this research study.

In Section 3.2, ecosystem-based is more closely looked into, and principles are reflected against the principles of sustainable development.

To conclude, Section 3.3, ties ecosystem-based management and sustainable development of the coastal zone together.

3.1 Coastal zone management approaches

Over the course of time, various integrated coastal zone management approaches have been proposed and have been evaluated in literature. To summarize, the main approaches, are the integrated coastal zone management (ICZM) from 1992 (Clark, 1992; Thia-Eng, 1993), the community-based coastal resources management of 1997 (CBCM) (Beger *et al.*, 2005; Pomeroy, 1997) and eco-system-based coastal management 2003 (EBM) (Katsanevakis *et al.*, 2011; P. S. Levin *et al.*, 2009; McLeod *et al.*, 2005; Ruckelshaus *et al.*, 2008). Similar between these approaches is the aim for sustainability thru balancing economic, ecologic and social values. Differences are found in the scope of the management approach and the areas focused on, as briefly shown in Table 1 below, based on the literature referred to above.

Table 1 - Comparison coastal zone management approaches

Management approach:	Scope:	Key focusses:
ICZM	Coastal Zone	Integrated, management, resource use
CBCM	Community-based coastal zone	Coastal resources, communities
EBM	Marine ecosystem	Ecosystem, integrated, interrelations, cumulative effect

3.1.1 Comparison

Again, all three principles are aimed at achieving sustainability in the coastal zone. Differences are found in the scope and key focusses. ICZM and EBM are actually pretty similar and more comprehensive than CBCM. The latter is mostly geared towards fishing communities and marine reserves, allowing for sustainable fishing (fish is a coastal resource) and [fish] production optimization.

To compare ICZM and EBM approaches, their definitions are looked into;

Integrated Coastal Zone Management: *‘A governance process whereby a series of integrated or coordinated responses are aimed at managing human-induced pressures and thus improving the state of coastal communities and environments.’* (Cicin-Sain et al., 1998)

Ecosystem-based Management 1: *‘An integrated approach to management that considers the entire ecosystem, including humans. The goal of ecosystem-based management is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need.’* (McLeod et al., 2005)

Ecosystem-based Management 2: *‘Ecosystem-based management is an interdisciplinary approach that balances ecological, social and governance principles at appropriate temporal and spatial scales in a distinct geographical area to achieve sustainable resource use. Scientific knowledge and effective monitoring are used to acknowledge the connections, integrity and biodiversity within an ecosystem along with its dynamic nature and associated uncertainties. EBM recognizes coupled social-ecological systems with stakeholders involved in an integrated and adaptive management process where decisions reflect societal choice.’* (Long et al., 2015)

From the definitions, similarities can be found in the holistic and integrated approach. Also the coastal zone, the environment and human impacts thereon come forward in both. A fundamental difference however, can be seen from the second part of the definitions. For ICZM, the goal is to coordinate human-induced pressures (tourism, fisheries, industries, agriculture and transport) to

achieve an improved state of the coastal zone. EBM however, turns the equation around by starting with the ecosystem, the human presences and their interdependence. It then aims to coordinate socio-economic values in such a way that the ecosystem is able to sustain and survive them.

Assessing the development of both coastal zone management approaches, ICZM and EBM, the ICZM can be seen as the predecessor of EBM (Haines-Young *et al.*, 2011b). Haines-Young *et al.* elaborate in their publication on 'the convergence of ICZM and the ecosystem approach' on how the need for an ecosystem approach, resulted from flaws found in ICZM practice. In short, 'ICZM policies were operationalized by regulatory measures like the environmental impact assessment (EIA) and resource use control. By design, these tools eventually led to permission for development or resource extraction. Merely limiting the licensing of resource use allows exacerbation of the process by a few stakeholders. The EIA report, in particular, served to satisfy government regulations usually at the expense of ignoring the interests of the community-at-large'. Coastal zone management practitioners, subsequently, expedited ways to go back to the integrated view on coastal zone management, starting from the marine ecosystem. This would integrate the complexity of natural cycles better. This shift in coastal zone management evolved to Ecosystem-based Management (EBM).

In current practice, many different ICZM strategies can be encountered. Most often based on the ICZM 'base-line' (Cicin-Sain *et al.*, 1998), current ICZM strategies have evolved and incorporate some sort of an ecosystem approach, by building on the existing management and evolving them towards an ecosystem-based management approach (Tallis *et al.*, 2009; UNEP *et al.*, 2011). The case for Mauritius will show no different in Chapter 0.

3.1.2 Conclusion: EBM approach

For this research study on sustainable marina development, the EBM approach to coastal zone development will be used. The decision relies on the comparison analysis above and the context of sustainable marina development as stated in Chapter 2. The reasoning is as follows;

- Sustainable development is broadly defined as a balance between the environment and development.
- A marina can only be called sustainable, when it is an integral part of a coastal zone that is managed for sustainable development (safeguarding key principles of cumulative impacts, intergenerational equity, long-term objectives)
- Sustainable development of the coastal zone needs to be ecosystem-based, to account for the complexity and interdependence of the environment and development. ICZM falls short at incorporating the complexity of natural processes and managing the relation of environment and development, which is the very essence of sustainable development.

3.2 Ecosystem-based management

In this research study, a framework will be provided for a present-day approach to marina development. To do this, the concept of ecosystem-based management is applied. Reasoning for this is twofold;

Firstly, out of the three discussed coastal management approaches, the ecosystem-based management is the most elaborated and recent approach to sustainable coastal zone development, as shown in the previous section.

Secondly, clear similarities exist between marina development, nature-based tourism and ecosystem management. Water quality, eco-tourism, aesthetics, biodiversity, (natural) shelter and ecosystem preservation are subjects important to sustainable marina development as well as to ecosystem-based management. Additionally, the location of future marina developments are often expected to be around environmentally sensitive areas, where an ecosystem-based approach can very well be applied and contribute greatly to sustainable development, as these are regions threatened by resource depletion and destruction of habitats (Millenium Ecosystem Assessment, 2005).

Although Ecosystem-based management has been introduced in Section 3.1 already, this section will elaborate more about the principles of ecosystem-based management, its merit and limitations. The information is based on a paper by (Long *et al.*, 2015), having executed a research study to identify key principles that currently² defines EBM, based on a subset of EBM theoretical/conceptual literature, bringing forward twenty-six different principles of EBM. The paper concludes a large variety in the way EBM has been defined in literature. Based on a frequency analysis, the key principles were determined and Long *et al.* (2015), have been able to develop an up-to-date² definition of EBM;

Ecosystem-based management (EBM): *'Ecosystem-based management is an interdisciplinary approach that balances ecological, social and governance principles at appropriate temporal and spatial scales in a distinct geographical area to achieve sustainable resource use. Scientific knowledge and effective monitoring are used to acknowledge the connections, integrity and biodiversity within an ecosystem along with its dynamic nature and associated uncertainties. EBM recognizes coupled social-ecological systems with stakeholders involved in an integrated and adaptive management process where decisions reflect societal choice.'*

The key principles have been adapted from the frequency analysis as follows. The following will be used in the remainder of the report as well. (Long *et al.*, 2015)

² Cut-off in papers taken into account has been medio 2010.

The six main principles are valid for marine and coastal management, have been frequently encountered in EBM literature and form a complete representation of present-day views on EBM.

- **Stakeholder involvement**, including
 - Integrated management
 - Societal choice
 - Economic context
 - Interdisciplinary
- **Sustainable development**, including
 - Long-term objectives
 - Intergenerational equity
- **Ecosystem Services perspective**, including
 - Ecological integrity & bio-diversity
 - Ecosystem resilience
 - Ecosystem connections
 - Scientific knowledge
- **Cumulative impacts**, including
 - Appropriate spatial & temporal scales
 - Distinct boundaries
 - Adjacent ecosystems
- **Multiple objectives**, including
 - Acknowledge trade-offs
 - Organizational change
 - Long-term objectives
- **Embracing change, learning & adapting**, including
 - Acknowledge uncertainty
 - Appropriate monitoring & risk management
 - Precautionary approach
 - Adaptive management

3.3 Ecosystem-based sustainable coastal zone management

To conclude past chapters on sustainable development, marina development and ecosystem-based coastal zone management, this section provides a clear summary of the findings.

Firstly, a marina development has been earmarked to be an integral part of coastal development. It is an example of a coastal development and anthropogenic impact that has a clear impact on the environment of the coastal zone. This environment includes the natural, social and economic environment.

Secondly, for sustainable development of the coastal zone, an integrated approach to coastal zone management is required. By honouring the complexity of natural processes, the interdependence between development and environment, the ecosystem-based management approach to coastal zone management is most suitable for achieving sustainable development.

Lastly, for sustainable marina development, the marina cannot be considered on itself; a sustainable marina will have to be an integral part of a sustainable coastal zone management plan, one that is ecosystem-based. Because, for sustainability, several principles need to be safeguarded on a system level.

The framework for sustainable marina development will incorporate this, by integrating an ecosystem-based coastal zone management plan. The plan overarches the system, referred to as the eco-region, and provides necessary input to the marina development stages.

As the current set of guidelines for marinas provides decent guidance for the detailed design stage, as well as for the operation and use stage, the framework will consider the prior development stage. To be more precise, the framework will provide guidance from the initial marina idea by an initiating party, to a preliminary marina proposal. By taking an ecosystem-based perspective in the framework, sustainable development will be part of the entire marina development cycle.

Part I. Developing the initial framework

Part I of the report considers the formulation of the initial framework, an ecosystem-based approach to sustainable marina development.

In Chapter 0, the place of the framework within an ecosystem-based coastal zone management plan is given. Its boundary conditions and most important elements to be included are given.

Chapter 5 focusses onto the ecosystem assessment of a marina development in a given eco-region. By applying the concept of Ecosystem Services – to be explained in Section 5.1 –, a tool is developed to assess the full array of interrelations between a marina and its environment.

The initial framework, including the ecosystem assessment as well as other critical steps, is given in Chapter 6 by means of a flowchart. The various steps and elements of the framework will be elaborated.

4. Framework essentials

The need for a framework has been explained in Part 0 of the report. The framework should provide guidance for initiating marina developments, to come to a marina development that is integrated in its environment, along principles and lines set out by the ecosystem-based coastal zone management plan.

On a system level, the so-called eco-region level, there is the coastal zone management plan, focussing on achieving a balance between development and the environment (sustainable development). A marina development would be an example of a coastal development impacting this balance.

The following figure (Figure 4) provides insight in how the framework for sustainable marina development relates to the eco-region management plan and a sustainable marina.

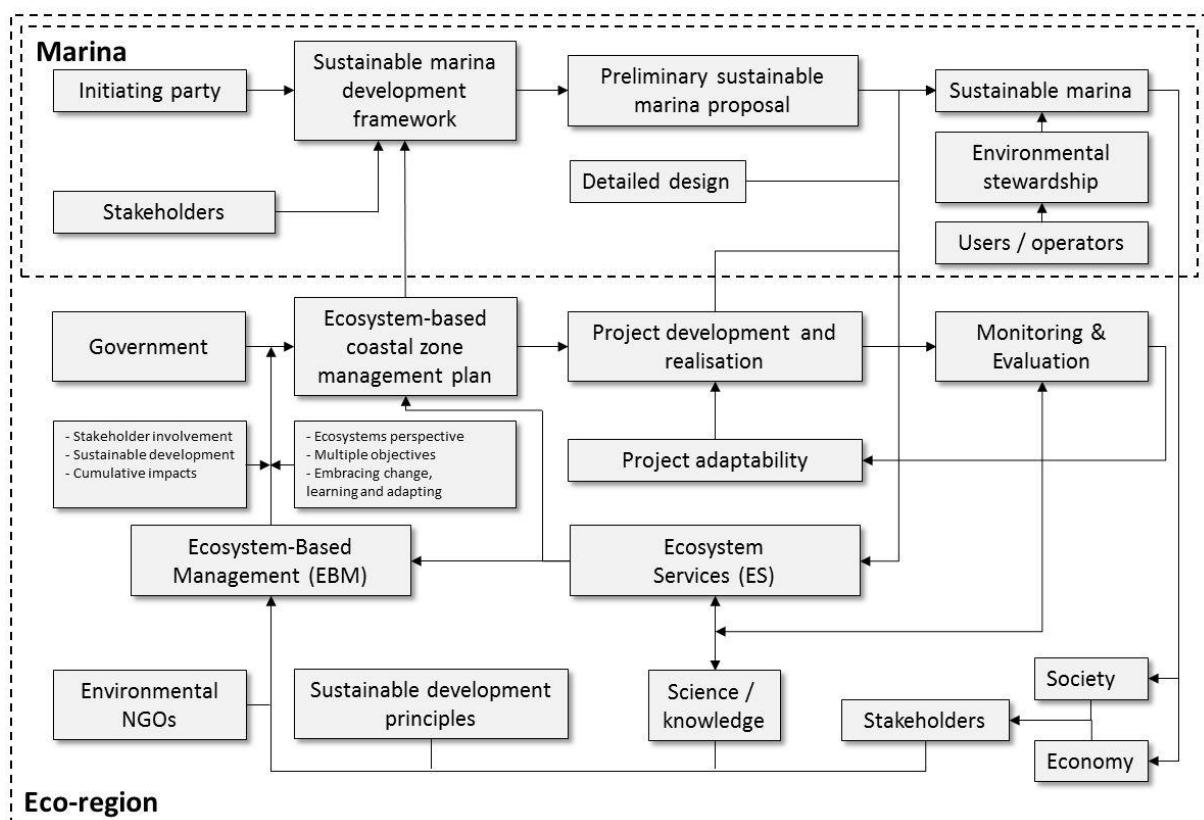


Figure 4 - Relation framework to ecosystem-based coastal zone management

The outer dotted line represents the eco-region border. This is the system level for coastal zone management. The inner dotted line represents the marina development. Inside the marina box, the framework for sustainable marina development has been pictured. This framework receives input from the system level, ecosystem-based coastal zone management and various stakeholders that are involved at an early stage of marina development. To elaborate a little on other parts of the scheme, the following can be said.

An ecosystem-based coastal zone management plan is built on EBM principles, which are listed in Part 0, Chapter 3.

The ecosystem-based coastal zone management plan not only provides guidance to marina developments, but to any and all projects that are being developed and realized.

In the top left of the figure the sustainable marina is depicted, being a result of a preliminary sustainable marina proposal, detailed design and environmental stewardship by its users and operators.

Lastly, monitoring and evaluation will take place for all developments and activities going on within the eco-region. It forms the basis for knowledge building, improving the coastal zone management plan and achieving sustainable development.

As the scheme is a continuous loop from EBM > coastal zone management > project development > monitoring > Science / knowledge > EBM, the principle of adaptability is acknowledged. Adaptability in EBM is represented by the principle of 'Embracing change, learning & adapting'.

5. Ecosystem-based management through Ecosystem Services

The framework will be ecosystem-based, as argued in Part 0. An essential part of the framework will therefore have to consider the relation marina development has with its surrounding ecosystem. Important decisions like location selection, and alternatives selection will need this information. Also, by considering the ecosystem in an early development stage, the marina development can be integrated in its environment much better, as relations are known. Potential complementing elements can be enhanced, critical points can be given appropriate attention and these focal points will guide subsequent decisions on detailed designing, materials used and the necessity of measures to control certain aspects of marina development.

To be clearer, some examples of above reasoning are given.

Example; A marina being developed in a tropical coastal environment, may have coral reefs in its near environment, as an important part of the coastal ecosystem. Coral reefs offer a great deal of Ecosystem Services, by supplying life cycle maintenance, nutrient cycling and aesthetics. Coral reefs also offer a certain degree of natural coastal protection, by attenuating waves over the reef. This quality aligns with the need for sheltered waters of marinas and hence, mitigates the need for structural works that provide protection against incoming wave action. This is an example of a complementing point, one that could well be implemented in marina design.

Example; On the other hand, marinas have a clear history of being a source of non-point source pollution, through storm water drainage, boat cleaning, boat wastes and onshore activities like servicing of boats, car driving and even walking your dog (Epsilon Associates Inc, 2001). The effects of the pollution can be hazardous to the local ecosystem by killing of animals and plants, or crippling their abilities to provide Ecosystem Services. As the marina, as well as the ecosystem, benefits from good water quality, pollution control should be a focal point in any marina development. Existing guidelines offer measures to control sewage, fuel spills and run-off of excess nutrients. By knowing in what way the pollution affects the local ecosystem, these effects can be targeted in the subsequent marina design stages effectively.

The way a certain marina interacts with its ecosystem, may vary by the type of marina considered, and by the type of ecosystem considered. To be able to evaluate the differences, a tool is developed to determine the interactions between a marina and the ecosystem, to take part in the framework for sustainable marina development.

First, in the next section, the concept of Ecosystem Services is elaborated. In Section 5.2, the tool will be elaborated.

5.1 The concept of Ecosystem Services

At several locations in this report so far, the concept of Ecosystem Services (ES) has come along. Ecosystem Services are defined as follows in the (Millenium Ecosystem Assessment, 2005), and adopted throughout literature;

Ecosystem Services: *‘Ecosystem Services are the benefits people obtain from ecosystems. These include provisioning, regulating, and cultural services that directly affect people and supporting services needed to maintain the other services.’*

Basically, the Ecosystem Services are grouped in tangible and non-tangible services to humans. A tangible group of ES, the provisioning services, provide resources directly to humans, like food (fish, sea weed), water and a selection of biotic materials and biofuels like shells, medicine and others. Regulating and maintenance services, represent the benefits obtained from regulation by ecosystem processes, like air/water purification, coastal protection and others. A third group, cultural services, encompasses the nonmaterial benefits that are obtained from ecosystems. Aesthetics and recreation are well-known examples, but also cognitive effects are part of this group of services.

In most definitions of ES, there is a fourth group, the supporting services. These are services that do not directly provide a service to humans, but are necessary for the production of other Ecosystem Services. Examples are nutrient cycling, life cycle maintenance and soil formation.

The concept of ES applies to all ecosystems on earth, terrestrial and marine. As the framework concerns coastal zone management, the set of ES as proposed by the Millennium Ecosystem Assessment has been adapted to link well with marine and coastal ecosystems by (Liquete *et al.*, 2013). Liquete transformed the set of Ecosystem Services to be used in marine and coastal ecosystems, based on the most common definitions of ES by the Millennium Ecosystem Assessment (Millenium Ecosystem Assessment, 2005), TEEB (TEEB, 2010), Beaumont (Beaumont *et al.*, 2007) and Haines-Young (Haines-Young *et al.*, 2011a).

To show the adaptations made, Appendix B shows the comparison between all considered sets of Ecosystem Services. It shows that none Ecosystem Services are left out, but some may have split up in two, and others have been merged into one. One large change Liquete *et al.* have made, is the subdivision of the supporting services category over the other categories of ‘provisioning’, ‘regulating and maintenance’ and ‘cultural’ services. This has been done to prevent double-evaluation of services when an ecosystem is assessed for the services it provides. In Appendix B, the individual Ecosystem Services are elaborated and defined.

Table 2 - Marine and coastal Ecosystem Services, adopted from (Liquete *et al.*, 2013)

Provisioning services		Regulating and maintenance services		Cultural services	
1.	Food provision	4.	Water purification	11.	Symbolic and aesthetic values
2.	Water storage and provision	5.	Air quality regulation	12.	Recreation and (eco-)tourism
3.	Biotic materials and biofuels	6.	Coastal protection	13.	Cognitive effects
		7.	Climate / weather regulation		
		8.	Ocean nourishment		
		9.	Life cycle maintenance		
		10.	Biological regulation		

Table 2 depicts the classification of marine and coastal Ecosystem Services, based on research done by Liquete *et al.* This classification is adopted throughout this research study.

The concept of Ecosystem Services can be used in the ecosystem-based framework as a tool to transparently assess the interrelations between a marina (elements) and its ecosystem (services). This will be generically applicable to any marina development at any ecosystem.

(Barbier *et al.*, 2008; Granek *et al.*, 2009) acknowledge the use of Ecosystem Services in current ecosystem-based management, as an improvement of the process of EBM. In their work, the concept of Ecosystem Services is used as a common language or currency on which to base negotiations, improved communication among groups with interests or differing world views. In the framework this will work as well. Because the set of ES represents the full ecosystem, and the list of marina elements and marina use (Part 0, Section 2.2) represents any marina, a cross-evaluation per interrelation will give an all-considering view on the marina's interrelation with its natural environment. It provides a handhold to base design considerations on, and also to open discussion between involved stakeholders, scientists and policy makers. As stated by Moreno *et al.*, integrating the concept of Ecosystem Services helps in dealing with the complexity of nature (Moreno *et al.*, 2013).

5.2 Marina – ecosystem interrelations tool

Now that the ecosystem has been represented by an array of Ecosystem Services, and the marina has been represented by the different marina- and marina use elements, a tool can be developed to assess the interrelations.

The tool will be generically applicable by assessing the interrelations per environment and setting. Although the interrelations and contribution/impacts between an ecosystem and the marina can be given shape by the tool, the complexity still exists, as the reciprocal effects are still hard to define and quantify. This makes it hard to accurately value an ecosystem service properly and thus management decisions difficult (Barbier *et al.*, 2011; de Groot *et al.*, 2010). This effect is acknowledged and even amplified for coastal zones as research on the marine and coastal Ecosystem Services is running behind – but increasing – compared to terrestrial ecosystem assessments (Liquete *et al.*, 2013). In this report, the knowledge gap is acknowledged and the framework produced will have to incorporate this. As research develops, and knowledge on marine and coastal Ecosystem Services grows, the framework will be more complete, refer to Part IV for an overview of conclusions and recommendations.

The way the tool will be able to deliver insight in the marina's integration into the environment is by getting an overview of all interrelations. A certain marina element may have predominantly more negative effects on certain Ecosystem Services than others, or oppositely, a predominantly positive effect on a set of Ecosystem Services. Also, from an ecosystems perspective, an ecosystem service can have a beneficial effect to a marina development (refer to the example of a coral reef as a coastal protection). These findings will deliver a set of focal points for that marina and ecosystem configuration. Findings will change when different types of marinas are considered and when that marina will be assessed for different ecosystems. On types of marinas, a good example could be a superyacht marina versus a small-scale pleasure boating marina. The first requires a large depth and sufficient space for navigating in and out the marina, as well as a range of facilities onshore. The latter requires less depth, space or onshore facilities, decreasing its effect on the ecosystem service.

The focal points will be important input for location selection (different ecosystems), for determination of appropriate type/size of marina, selection of alternative marina designs and the establishment of a initial monitoring plan and risk assessment.

Additionally to the focal points, an understanding of the complete marina – ecosystem interrelations is obtained. Where current practice may avoid any sensitive ecosystem out of uncertain consequences, the tool will show where difficulties are and potentially, where possible options are to be able to implement a marina development in a certain sensitive environment, targeting the critical points that may arise.

Although new doors to marina development may open, other marina developments will prove not possible to integrate in the environment, by too heavy impact on the environment. This, however, is also valuable information, as these marina developments may otherwise be continued to be developed to the point that no EIA license can be obtained, or worse, when the marina is realized and the ecosystem is heavily impacted, leading to a degradation of the ecosystem and a loss in Ecosystem Services that it provides.

Without filling out the full scheme for a given context of a marina and an ecosystem, the tool is designed as follows (Figure 5);

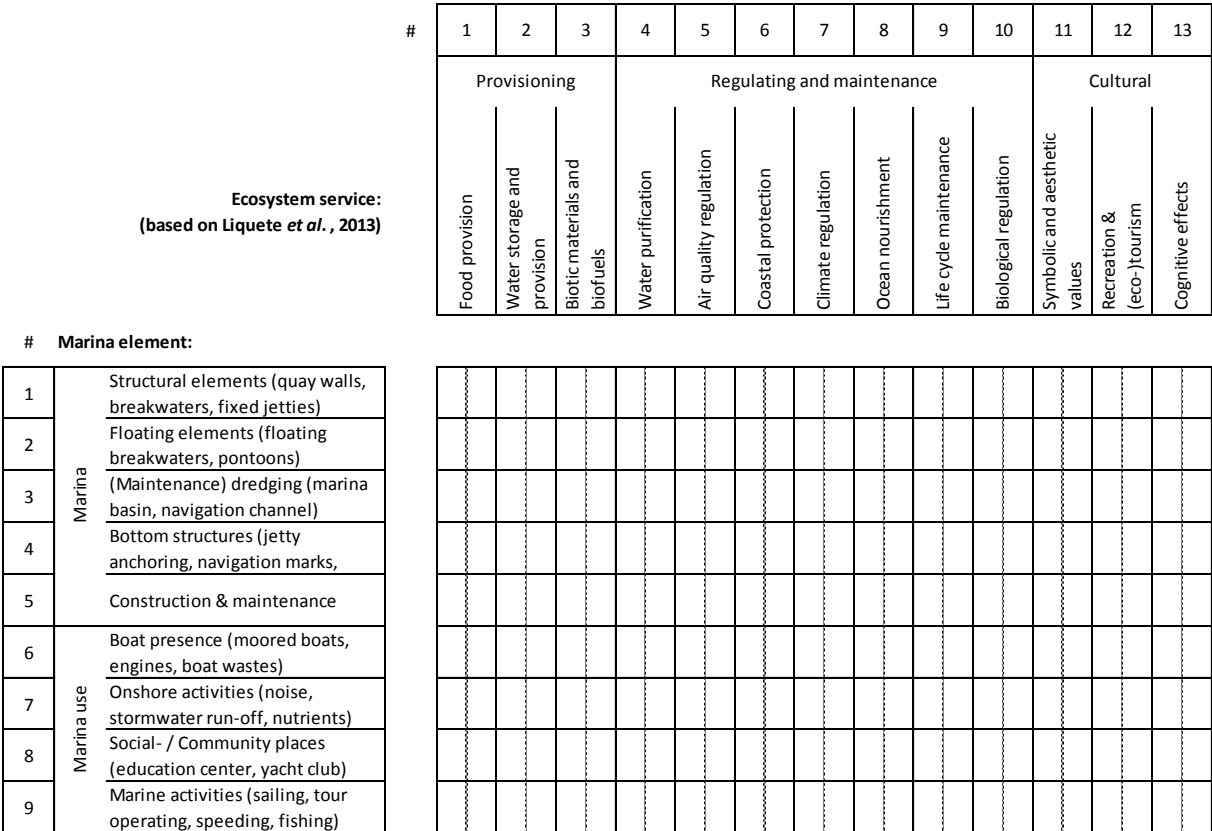


Figure 5 - Basic marina - ecosystem interrelations tool

The scheme is set-up by introducing a matrix, with the Ecosystem Services on the horizontal and the marina functions on the vertical. For each link between a single marina element and an ecosystem service, the relation is indicated twice. Firstly, the impact the marina element has on the ecosystem service, and secondly the other way around, indicating the way the ecosystem service affects the marina element.

Each interrelation, going both ways, can be given a score ranging from double negative (- -) to double positive (++) . At the cross-over, or with a positive as well as negative score, one fills out (+/-) . For no relation, a (0) is entered. To improve understanding, the scores will be colour coded as well, ranging from red for (- -) to green for (++) .

To be able to fill out the scheme and use the tool, a lot of information on surrounding ecosystems and the way it relates to marina elements is needed to indicate a certain relation. As the framework is ecosystem-based, this makes sense. To help with this, the ecosystem-based coastal zone management plan should keep track of all obtained information from previous projects and developments in the area, supplemented with adequate stock-taking and scientific research. This information will be shared upon marina project initiation, together with information on the eco-region policy that is operational in the given area of interest.

Use of the tool, and completion of ecosystem-based marina developments, will deliver valuable information back to the ecosystem-based coastal zone management, improving information purveyance for future coastal developments and marina developments in particular. This cycling of information aligns with EBM principles of embracing change, learning and adapting. It also refers to the sustainable development principle of the precautionary approach, as the more information is available, the more certain impacts and effects of anthropogenic integration into the environment will be.

6. The initial framework

Below, the developed initial framework is depicted. In the following section, steps are elaborated.

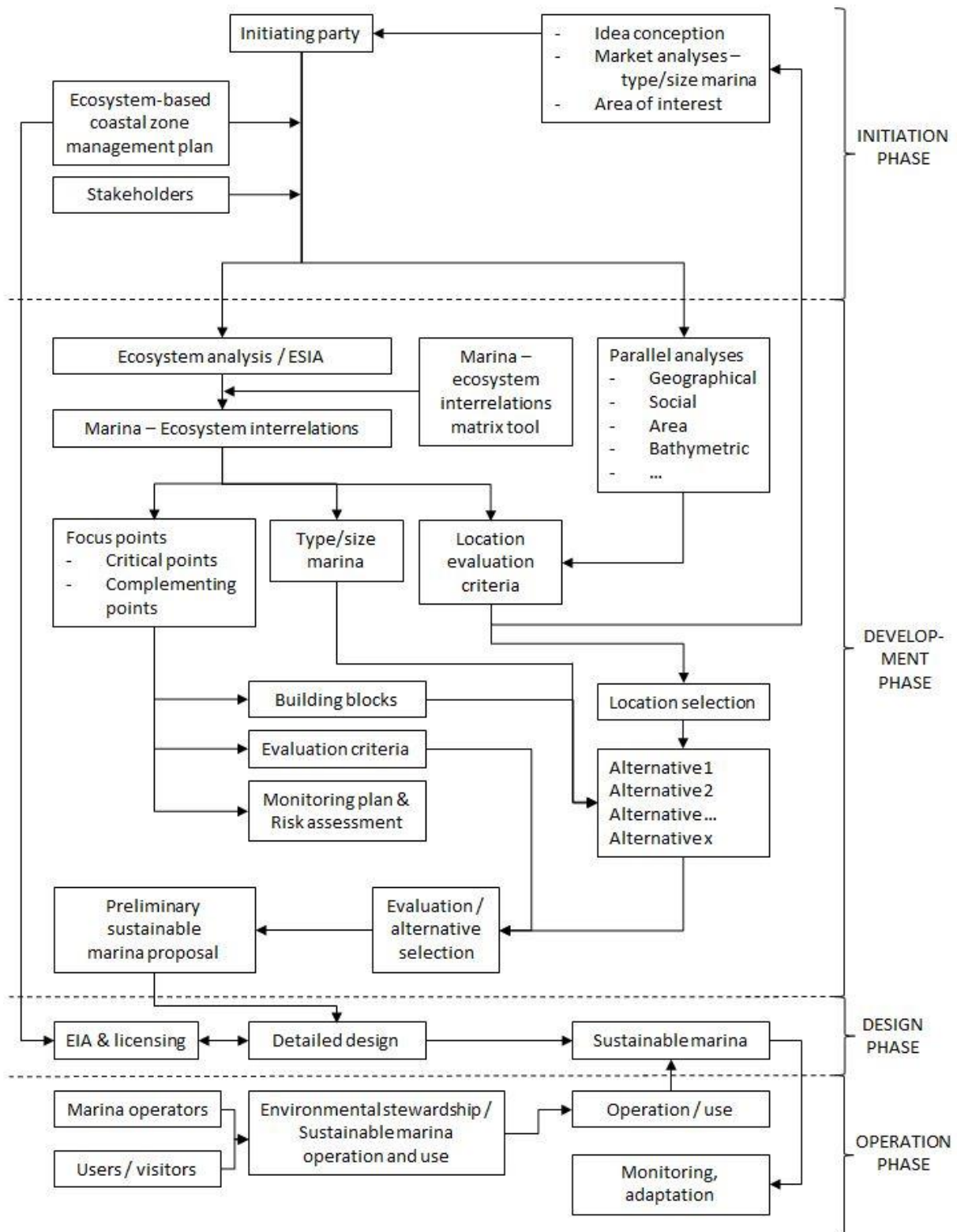


Figure 6 - The initial framework to sustainable marina development

6.1 Initial framework elaboration

The framework in Figure 6 handles the development cycle from the starting point – the initiating party – to a preliminary sustainable marina proposal (see Figure 4). As stated before, the framework has an ecosystem-based perspective, coming forward in a focus on the environmental assessment. The framework is elaborated below, phase by phase.

Initiation phase

During the initiation phase, an initiator takes the first step of a marina development by expressing an interest. An initial study follows, leading to a general idea of what type and size a marina is aimed for, what the marina's or initiator goals are and where the marina roughly should be developed. An initiating party could be of different kinds. It could be driven by the government, an investor or a local community. Depending on the driving force, goals for the marina may differ. An example could be a real estate investor. First of all, for an investor return on investment and profits will be critical. This will highlight the commercial part of the development cycle, by for example adding accommodations (or perhaps the marina is added to the existing accommodations) or extra services and facilities. A government may be able to take a longer term view on a marina development investments, and foremost wishes to create value to the area and/or attract more visitors.

After expression of the initiating party's interest, the nation-wide ecosystem-based coastal zone management plan needs to be consulted. Nearly every coastal region in the world is governed by a coastal zone management plan. Whether this is driven by ecosystem-based-, community-based- or function-based considerations will change over nations and continents. However, for this framework, the assumption is made that an ecosystem-based coastal zone management plan is present. This assumption is made because – as deduced from literature in Part 0, Chapters 2 & 3, is the required management approach for sustainable (marina) development.

Input from the ecosystem-based coastal zone management plan for the marina development will be the overview of the coastal zone (eco-region) and its ecosystem(s). It offers insight in what functions are combined in the area, explicitly with their respective interrelations with the ecosystem. By introducing a marina development initiative, the coastal zone management plan indicates potential locations, restrictions, focal points and guidance. The latter will be done by delivering the framework for marina development, developed during this research study. Also, it incorporates regional/local (environmental) regulations, so that they are incorporated at this stage of marina development as well, smoothening the EIA and licensing procedures.

Another strong input is from different stakeholder groups, indirectly through their integration in the ecosystem-based coastal zone management plan, and directly when there is an interest in the

envisaged marina development. As the ecosystem-based management approach aims to integrate functional requirements, societal choice, socio-economic factors and ecological values it is critical to involve stakeholders representing these values during the initiation phase. Benefits for the project include more information, increased trust and increased support (MEAM, 2011). Across literature and online, many tools are developed to improve stakeholder involvement and engagement.

Development phase – analyses

When a project has been initiated, it enters a planning and development phase. Project outlines and goals are given, but no location, design or detail is set yet. The first stage of the development phase involves carrying out analyses on all relevant aspects. There are area analyses, geographic analyses, market analyses, social analyses, bathymetric and hydrographic analyses, and explicitly included in this framework, the ecosystem analysis. During this analysis, an understanding of the present ecosystem in the area is obtained. It assesses the status of ecological processes and shows where the sensitive or robust elements are. Ultimately, this knowledge is captured in Ecosystem Services. Complemented with the conceptual idea for a marina, the Ecosystem Services will deliver the input for the ecosystem – marina interrelations tool, as described in previous chapter.

The tool delivers a series of products of value to the development process. First of all, it delivers input to the location selection process. It will be able to remove potential locations, add locations and add criteria to the remaining set of locations can be evaluated to. Secondly, the matrix will give focal points for the marina development process. There may be interrelations between a marina element(s) and the ecosystem where the two are complementing to each other. There may also be interrelations that are potentially harmful to one another, the so-called critical points. Where the marina and the ecosystem can be complementary to each other, these relations should be kept in mind during the design phases. Critical points also require special attention, and having this knowledge before starting the design process will help towards a smooth sustainable marina development process. The focal points also provide additional criteria to the selection of alternative designs. Additionally, the ecosystem analysis provides valuable input for risk assessment and monitoring agendas. Risk assessment and monitoring is an essential part of ecosystem-based management. It refers back to the EBM key principle of ‘Embracing change, learning & adapting’ (Section 3.2).

From literature, best practice and ongoing research, many examples can be identified where integrated solutions for aspects of the design are developed. These examples treat certain interrelations between an ecosystem service and for example a marina element. They should be incorporated in the framework as ‘building blocks’ to provide suggestions and handholds during

design phases. Examples include artificial reefs, floating breakwaters, drainage systems, habitat creating piles, dikes or pontoons et cetera (Deltares *et al.*, 2013).

Development phase – location selection

By performing the set of analyses, knowledge is obtained about the boundary conditions, requirements and context of the project. As shown in the framework flowchart, the analyses lead to a location selection process. Specifically including environmental considerations from the ecosystem analysis, either a sub-region within the area of interest/ eco-region can be selected, or a feedback loop goes back to the idea conception to start with a different goal or area in mind, for the case that none of the locations match the conditions for the project. Another, more nuanced option is to propose different locations, potentially with remarks. For example, a certain location may be perfect from a socio-economic point of view, but ecosystem-based requirements can only sustain a small-scale marina. Or a location is able to fit a full-fledged marina in the ecosystem, but finds itself at an unattractive location for users or commercial activities.

Development phase – alternatives

As a (selection of) location is now given for the project, the type and size of a marina for that location is found, and interrelations between the envisaged marina and its environmental context are known, the alternatives development phase starts. With focal points, building blocks and criteria in mind, conceptual designs can be produced that incorporates the perspectives of the coalition of stakeholders and integrates functional requirements, societal choice, socio-economic factors and ecological values.

Besides the project specific context and goals, it is important to continue to pursue the key elements of EBM (Section 3.2);

- Stakeholder involvement,
- Sustainable development,
- Ecosystem Services perspective,
- Cumulative impacts,
- Multiple objectives,
- Embracing change, learning & adapting.

The latter includes a degree of flexibility in the alternatives and a monitoring plan. The element of sustainable development requires a long-term perspective, and future growth and/or marina development potential should be included in the design of alternatives. Sustainable development implies that the marina serves the sustainability goals in the short-term as well as in the long-term, under changing future conditions (intergenerational equity, refer to Part 0, Section 2.1)

Development phase – evaluation

The last stage of the development phase will involve an evaluation of the alternatives. Criteria root from the different analyses and are weighed according to stakeholder perspectives. As a prerequisite, the alternatives will adhere to the key elements of EBM, in order to sustain the holistic approach throughout the development process.

The product of the evaluation stage is the preferred alternative, and will be presented as a preliminary sustainable marina proposal.

This is the final product of the framework for sustainable marina development, together with all information acquired on focal points on environment integrations, monitoring- and risk assessment plans and important elements to incorporate in the design detailing.

Design phase

The starting product for the design phase is the preliminary sustainable marina proposal, developed according to the framework for sustainable marina development, which is embedded in the ecosystem-based coastal zone management plan. The proposal offers flexibility in its design and lacks detail. It is accompanied however, with specific focal points, potential building blocks and a monitoring strategy.

In the design phase, the design of the marina will iterate with stakeholder's perspectives. A large stakeholder for the design of the marina will be the governing authority, demanding adherence to policy and regulations, by means of an EIA or SEA for example. As these interests have been present at the start of the development phase, and an understanding of the environmental context the marina proposal is placed in has been acquired, including a location selection, the expectation is that the required adaptations will be minimal and licensing procedures cost-, time, and effort effective.

The result of the design phase will be a detailed design of a sustainable marina, where the functional requirements are met, and the marina can be realized in a way that is consistent with the area's ecosystem-based coastal zone management plan, and has found a sustainable position towards its environment. Positive, complementing features of the marina and the ecosystem will be incorporated, and negative relations negotiated. The ecosystem where the sustainable marina is being developed in will be able to continue to provide Ecosystem Services.

Operation phase

The last phase in the marina development cycle is the operation phase. Here, the sustainable marina design has come to realization and is being maintained, used and operated. Growth of the marina or an increase in usage also may occur during this phase.

As the research study focuses on the development phase of the life cycle, this phase has been left to existing knowledge and practices. These are well present, as have been introduced in Part 0. Environmental stewardship, best practice and sustainable management are required to be carried out in this phase. With knowledge on how the marina interacts with its surrounding environment, measures and best practices can be applied effectively for the better.

For this phase, a monitoring strategy is taken from the development and design phase. As knowledge on interrelations with the environment and in-depth understanding of ecological processes is being explored, the marina development cannot be missed as an opportunity to gain knowledge on the subject. This has been depicted by an arrow running from monitoring, back to the ecosystem-based coastal zone management plan in Figure 6. The marina will also have to respond to findings and actual developments over time. It is the marina management's task to continue to fulfil the articulation of a sustainable marina and therefore contribute to natural biodiversity, ecosystem functioning and the ecosystem's ability to provide Ecosystem Services.

Part II. Framework comparison

In Part 0, the case of Mauritius has been introduced. The island will be the location for the case study, where a marina will be developed by adhering to the framework from this research study. The case study is given in Part III.

Before that, this Part will compare the initial, ecosystem-based framework, developed in Part I, to existing practice in Mauritius. This may deliver insight in the difference of views on coastal zone management, and to some degree, marina development.

In Section 7.1 the way of comparison is given. Subsequent sections, Sections 7.3 - 7.5, present the observed differences and similarities. The final section of Chapter 0, Section 7.6, ties a conclusion to the comparison and draws lessons learned.

7. Initial framework compared to Mauritian practice

The framework has assumed an ecosystem-based coastal zone management plan to be in place for sustainable marina development. In Part 0, the case has been made, that to reach sustainable development in the coastal zone, the management approach has to be ecosystem-based. In short, a marina development cannot be sustainable on its own, and has to be considered at the system level of the ecosystem (or eco-region). For this area, an ecosystem-based coastal zone management plan safeguards a series of elements that are elementary to sustainable development that cannot be considered on the marina level only. These elements of sustainable development are embodied by the principles of 'long-term objectives', 'cumulative impacts' and 'multiple objectives'. Moreover, the aspect of ecosystem-based management 'Ecosystem Services perspective' acknowledges the complexity of nature and the degree of interdependence within ecosystems, and between the natural environment and its socio-economic environment. The latter is a distinctive principle compared to ICZM practices

However, ICZM strategies around the world have adapted and many versions are currently in practice (Haines-Young *et al.*, 2011b; Tallis *et al.*, 2009). In Mauritius, an ICZM strategy is in the process of being implemented. An engineering consultancy firm, Landell Mills, has developed this strategy for the island of Mauritius in 2011. To assess the 'version' of this ICZM strategy, and to compare it against the EBM strategy, this chapter makes comparisons at different levels. Which comparisons are made, is elaborated in Section 7.1.

7.1 How to compare?

The comparison will be done at two levels. First, on the system level of coastal zone management, the difference between an ecosystem-based coastal zone management plan as defined in Part I and the Mauritian ICZM strategy will be evaluated. Also, to obtain the right perspective on the Mauritian ICZM framework, its relation to the traditional ICZM principles is looked into. From literature one knows, that there are large differences to be seen in current ICZM strategies (Haines-Young *et al.*, 2011b). The trend shows a movement of ICZM strategies incorporating more of an ecosystem perspective, moving towards an ecosystem-based coastal zone management (UNEP *et al.*, 2011).

To compare the ICZM strategy of Mauritius with the EBM approach, the key principles are looked into. From the field work executed in Mauritius, the Mauritian ICZM strategy has been obtained (Landell Mills, 2010). This strategy has been developed in 2009 by a British consultancy firm, commissioned by the Ministry of Environment and the National Development Unit of Mauritius. The strategy states the key principles applied, and the way of implementation in Mauritius. The key principles can be evaluated against the key principles of EBM, as defined in Part I and against the

core elements of ICZM as defined by (Cicin-Sain *et al.*, 1998). Similarities and differences can be derived and evaluated.

The second level of comparison is done on the specific marina development level. The initial framework from Part I is compared against current documents on marina development in Mauritius. As Mauritius lacks a proper marina (see Part III), and little experience exists on marina development, only two guidance documents have been found (Ministry of Environment & Sustainable Development, 2013a; Ministry of Housing and Lands, 2004). This document aims to guide marina planning and design, in order to adhere to Environmental Impact Assessment (EIA) requirements. It presents an exemplary table of contents for an EIA report, with all chapters and required info shortly explained. This document should stimulate the developers and consultants to assess the impact that the marina will have on the environment, and what the measures will be to deal with these impacts.

From the guideline, the development process is extracted in Paragraph 7.5.1, and this can be compared to the initial framework for sustainable marina development, as developed in Part I.

7.2 ICZM Framework Mauritius

In the Republic of Mauritius, the need for an ICZM framework was identified in the 1999 National Environment Strategies, giving rise to a series of studies, investigating coastal erosion in 2003, bathymetry maps and habitat resources atlas in 2004, potential marina and bathing areas in 2005 and the mapping of environmentally sensitive areas (ESAs) in 2010 (ASCLME, 2012a). In 2002, the Environment Protection Act was renewed. Per section 50, the EPA 2002 set up an ICZM Committee. With help of British consultants, an ICZM framework was completed in 2009 and is being implemented from 2010. The framework comprises of an ICZM strategy, including implementation and financial strategies, a good practice guidance plan for coastal activities and action and area plans for six pressure zones. The ICZM framework has been incorporated in the National Development Strategy, providing the strategic framework for sustainable development. The National Environmental Policy (NEP), 2008, provides a policy base from which to develop the ICZM Policy Framework within Mauritius. Also, the Republic of Mauritius has initiated the Maurice Île Durable (MID) project in 2008, aiming at a sustainable future for the island state (Ministry of Environment & Sustainable Development, 2013b). The environment, including sustainable coastal zone management, is one of its pillars, showing that the topic receives much attention and effort from the Mauritian government.

At the time of the author's field trip, the implementation of the ICZM strategy is ongoing; restructuring of the institutional structure, data accumulation and distribution and improving of current coastal zone management. Current coastal zone management involves an EIA/PER (Preliminary Environment Report) mechanism and compliance to Building and Land Use Permit (BLUP) requirements. The Mauritian ICZM framework aims to build onto this mechanism, filling existing gaps of enforcing capacity, information distribution across management levels and institutional capacity. These developments will contribute to a mechanism of communication, collaboration and coordination in the various decisions and activities of the different agencies involved in the coastal zone (Landell Mills, 2010).

The Mauritian ICZM Framework has been based on the following four key elements, obtained from the Final Report (Landell Mills, 2010);

- Living with environmental limits
 - Ecosystem approach
 - Work with natural processes
 - Precautionary principle
 - Provide for local specificity
- Achieving a sustainable economy

- Broad, holistic perspective
- Long-term perspective
- Recognize that change in human behaviour is central to environmental sustainability
- Sustainable production and consumption patterns
- Promoting good governance
 - Environmental governance and accountability
 - Support and involve all relevant decision-making bodies
 - Promotion of policy dialogue culture
 - Global Code of Conduct
- Encourage equitable access and use of resources
 - Intra-generational equity
 - Inter-generational equity
 - Polluter Pays Principle

7.3 Mauritian ICZM practice vs. ICZM 'base-line'

Before comparing with the EBM key elements, these elements are discussed with regard to the general ICZM elements. As introduced earlier in this chapter, current ICZM strategies across the world show some large differences, indicating its own development over time (Haines-Young *et al.*, 2011b).

Reading into the ICZM case of Mauritius, the newly adopted framework has indeed developed from the traditional ICZM values. In the book written by Cicin-Sain *et al.*, 'Integrated Coastal and Ocean Management: Concepts and Practices', 1998, the principles of Integrated Coastal Zone Management are elaborated. The work has been and is being cited across scientific papers according to the literature databases and educational literature, indicating the principles are used as a 'base line' for Integrated Coastal Zone Management.

The principles are largely in accordance with the key elements adopted in the Mauritian ICZM framework. Naturally, the goal is identical; to contribute to sustainable development in the coastal zone. In Table 3 the principles and key elements are bullet-pointed. A listing of similarities and differences is given also.

Table 3 - Comparison of principles between traditional ICZM 'base line' and Mauritian ICZM

ICZM 'base-line' (Cicin-Sain <i>et al.</i> , 1998)	Mauritian ICZM (Landell Mills, 2010)
Environmental safeguards principle	Living with environmental limits
Prevention of (transboundary) harm through anticipatory measures	Ecosystem approach
Precautionary principle	Work with natural processes
Enact and implement effective environmental legislation	Precautionary principle
	Provide for local specificity
Interrelations & Integration	Achieving a sustainable economy
Inter sectoral	Broad, holistic perspective
Environment - Development	Long-term perspective
	Recognize that change in human behaviour is central to environmental sustainability
	Sustainable production and consumption patterns
Transparency and other process-oriented principles	Promoting good governance
Public involvement	Environmental governance and accountability

Encouragement of participation	Support and involve all relevant decision-making bodies
Access to environmental information	Promotion of policy dialogue culture
	Global Code of Conduct
Inter- and intragenerational equity	Encourage equitable access and use of resources
	Intra-generational equity
Polluter Pays Principle	Inter-generational equity
Internalization of environmental costs	Polluter Pays Principle
Right to develop	
Right to live and to develop for every human being	

Below, a listing of similarities and differences is given. Here, a conclusion can be drawn on what kind of framework is being implemented in Mauritius.

Similarities:

- Sustainability. Although the base-line principles do not name sustainability, the principle of ‘interrelations & integration’ and the literature in the book clearly state sustainable development and the complexity of societal, economic and environmental systems. The Mauritian ICZM elements of a ‘broad, holistic perspective’, ‘a long-term perspective’ and the ‘human behaviour – environmental sustainability’ relation, relate to the aforementioned principle of ICZM. To be more precise, the broad, holistic perspective involves the integration of environmental concerns into the economic and social development and the cross-sectoral integration of policy-making.
- Environment. Stated literally in both lists is the ‘precautionary principle’, and text from both sources is in accordance (preventive approach, providing for adaptive management). The other elements stated in the Mauritian ICZM, the ‘ecosystem approach’, ‘work with natural processes’ and ‘local specificity’, do not root from the ICZM base-line. This will be discussed in the Differences section.
- Governance. Both set of principles advocate cross-sectoral involvement of stakeholders. Also public involvement and transparent decision-making makes an appearance in both.
- Equitable access and use of resources. Quite literally, in the principles, as well as in both documents, ‘intra-generational equity’, ‘inter-generational equity’ and the ‘Polluter Pays Principle’ are adopted.

Differences:

- Environment. The largest and foremost difference is on the environmental topic. The Mauritian ICZM, as well as other more recent ICZM frameworks, has adopted an ecosystem approach to deal with environmental health, resource uses and ecological processes. The fact that the Mauritian ICZM framework incorporated the 'ecosystem approach' and 'work with natural processes' elements, shows that the set of principles has evolved from the base-line principles. Landell Mills elaborated on this in their framework report; the ecosystem approach is an overriding principle which tracks closely onto the principle of working with natural processes. For the framework, the ecosystem approach is operationalised by working with natural processes, rather than large-scale rehabilitation and/or replacement of ecosystem structures.

To conclude the comparison between the traditional ICZM base-line and the Mauritian ICZM framework based on the two sets of principles, one can say the framework involves a developed version of ICZM. First and foremost there is a great deal of similarities, which in their turn prove the Mauritian ICZM is based on the ICZM base-line. Secondly, some differences can be seen, that show that the Mauritian ICZM has adopted a version of the ICZM base-line;

The incorporation of an 'ecosystem approach' within the 'living with environmental limits' principle, is an evolution of ICZM that has been recognized in literature; Literature shows the traditional ICZM set of principles is evolving to incorporate the ecosystem approach (Forst, 2009; Haines-Young *et al.*, 2011b). However, Haines-Young *et al.*, state that considerable challenges remain in embedding the ecosystem approach in decision making, but when successful, will lead to an operational and contemporary convention capable of achieving sustainable development (when implemented universally and over the proper regional scales). The way the ecosystem approach is embedded in the Mauritian framework, is by working with natural processes. Whether this will be successful is yet to be seen in practice, as implementation of the framework is ongoing. The framework report however, does not yet aim to assess the ecosystem on hand holistically, as is required for an ecosystem approach. A key aspect of the ecosystem approach is that functioning and integrity of the ecosystem are vital to maintain in order to maximise societal resources gained from the coast (Ecosystem Services). This implies an understanding of the ecological processes, the ecosystem structure and interactions between organisms and their environment. These elements do not come forward in the framework implementation strategy.

7.4 Mauritian ICZM practice vs. EBM

To make this comparison, the different sets of principles are again compared to each other, supported by the relative literature (Landell Mills, 2010) and (Long *et al.*, 2015).

Table 4 - Comparison of EBM principles to Mauritian ICZM principles

EBM (adopted from Long <i>et al.</i> , 2015)	Mauritian ICZM (Landell Mills, 2009)
Stakeholder involvement	Living with environmental limits
Integrated management	Ecosystem approach
Societal choice	Work with natural processes
Economic context	Precautionary principle
Principles of equity	Provide for local specificity
Sustainable development	Achieving a sustainable economy
Long-term objectives	Broad, holistic perspective
Ecosystem Services Perspective	Long-term perspective
Ecological integrity & bio-diversity	Recognize that change in human behaviour is central to environmental sustainability
Ecosystem resilience	Sustainable production and consumption patterns
Ecosystem connections	Promoting good governance
Scientific knowledge	Environmental governance and accountability
Cumulative impacts	Support and involve all relevant decision-making bodies
Appropriate spatial & temporal scales	Promotion of policy dialogue culture
Distinct boundaries	Global Code of Conduct
Adjacent ecosystems	Encourage equitable access and use of resources
Multiple objectives	Intra-generational equity
Acknowledge trade-offs	Inter-generational equity
Organizational change	Polluter Pays Principle
Embracing change, learning & adapting	
Acknowledge uncertainty	
Appropriate monitoring & risk assessment	
Precautionary approach	
Adaptive management	

In Table 4, the different sets of principles are given. On first glance, one can observe a different perspective from both sets of principles. The ICZM principles include over half of the (sub-)principles on the management topic, whereas the EBM set of principles only names similar elements sparingly. The EBM principles however, show a more holistic approach, taking into account the cumulative impacts, cross-boundary and adjacent ecosystems, along with a much more elaborated principle of environmental health, under the principle 'Ecosystem Services perspective'. These differences will come forward, along with the similarities in below comparison.

Similarities:

First of all, as discussed in Part I, both management approaches aim at achieving sustainability in the coastal zone. Differences are found in the scope and key focusses. Those are reflected by their respective key principles.

- Sustainability. Both approaches aim at achieving sustainability in the coastal zone by taking a long-term perspective and an integrated approach to balance human and environmental considerations. This is reflected in the list of principles by 'stakeholder involvement', 'sustainable development', 'achieving a sustainable economy' and indirectly by many of the sub-principles stated. Ultimately, the collective of principles is required to reach the sustainable development goal.
- Organization. Both approaches place strong emphasis on the way the approach should be implemented in the institutional structure. Communication and transparency is brought forward as priority goals to achieve 'good governance', 'multiple objectives' and 'integrated management', to name a selection. In practice though, as stated in literature, the ICZM approach has delivered a more succesful platform to guide coastal zone management, but failed to take an holistic approach on the environmental part, with degradation and, in some cases, collapse of ecosystems (Curtin *et al.*, 2010).
- Adaptive management. Both management approaches include an adaptive management approach, acknowledging the complexity of the system at hand and the fact that scientific understanding is not yet complete. For the Mauritanian ICZM framework, the precautionary principle embodies this aspect. However, the EBM approach does take this further, by actively working towards a deeper understanding of the ecosystem considered. See the differences section for the differences between the two approaches on this aspect.

Differences:

- Environmental approach. Although the Mauritian ICZM framework has adopted an ecosystem approach and aims at working with natural processes, this does not provide the same basis for environmental considerations as EBM does. In EBM a focus on the ecosystem as a whole is kept throughout the process. It incorporates an 'ecosystems services perspective' (Curtin *et al.*, 2010). In short, EBM seeks to broaden the scope of traditional resource management (ICZM) so that it considers a wider range of ecological, environmental and human factors in the exploitation of resources, i.e. a more holistic way of understanding how ecosystems work (Arkema *et al.*, 2006). See also the sub-principles of 'ecological integrity & bio-diversity', 'ecosystem resilience', 'ecosystem connections' and 'scientific knowledge'. EBM aims to resolve the ICZM's inadequacies by providing a system of management that views the ecosystem as a whole, where all the drivers and all their impacts are considered in relation to their effects on ecosystem functioning. It also involves broadening stakeholder involvement and evaluation of multiple simultaneous drivers and pressures on ecosystems (Curtin *et al.*, 2010).
- Adaptive management. Having addressed the similarity in approaches, being that both do acknowledge uncertainty, there is also a large difference to be seen. EBM has adopted the aspect as a leading principle; 'embracing change, learning & adapting'. Herein, uncertainty about processes and consequences is acknowledged, realizing that all the factors affecting ecosystems are not at hand. The scientific consensus statement on marine EBM (McLeod *et al.*, 2005) believes that levels of precaution should be proportional to the amount of information available. Adaptive management in EBM involves focussing on management as a learning process or continuous experiment (Curtin *et al.*, 2010; Forst, 2009), which corresponds to the aforementioned principle.
- Cumulative impacts. An important difference to be observed is the due regard to the presence of cumulative impacts on (part of) an ecosystem. It closely relates to the adaptive management principle, as the fact that numerous factors, known and unknown, will affect the ecosystem at hand. EBM considers this aspect through the principle 'cumulative aspects'. It is an integral part of considering a system holistically, as it aims at setting appropriate (tuned to the considered system) spatial and temporal scales. This EBM sub-principle is a notable difference from ICZM, where political or jurisdictional borders and timeframes are typically used (Forst, 2009). It does require a high level of multi-level and inter-organizational cooperation and communication.

7.5 Mauritian marina development guideline vs. the initial framework

In Mauritius, a lack of marinas and yachting scene has been observed by the author, during a field trip in October 2016. Although there is a clear potential for marina development (BOI, 2013) due to the Mauritian tropical climate, its scenery and (high-end) tourism business, marina development is not highly prioritized on the country's agenda. Similar locations to Mauritius, offering a reference, are the island of Réunion and the Seychelles archipelago, both with a highly developed marine tourism scene, including large numbers of marinas.

In Mauritius, only one, very small, public marinas exists. There are, however, numerous anchorages in bays scattered around the island and there is a couple of jetties, that are often associated with hotels and/or resorts. Also, there is a real estate marina being built, that will become operational towards the end of 2016. This marina is aimed at private docking, owned by customers that rent or have a house in the La Balise project. The one marina that is present in Mauritius is located in the Port Louis harbour, and is able to accommodate twenty yachts with very basic facilities.

There are multiple reasons why Mauritius has not advanced the way as for example Réunion or other small island states have. Reasons are cultural, financial, political and also environmental. According to the website of the Ministry of Environment, numerous proposals for marina developments have been submitted, and consecutively, disapproved by the Ministry. In an interview with the Minister and his commissaries, November 2015, it became clear that the main issue is the making of a 'proper' Environmental Impact Assessment (EIA). In interviews with the party on the other end, the initiating party, the opinion is stated that it is too hard to comply to the environmental policy.

There are two documents that the government has published on the topic of marina development. Firstly, the marina design guidance document that is part of the Planning and Policy Guidance 2004 (Ministry of Housing and Lands, 2004). The four-paged document gives some rough design guidelines on type, size and pier geometry. The content is by no means extensive, nor complete and does not refer to Mauritian regulations. Secondly, the Ministry of Environment has published a guideline for marina developers to prepare an EIA report that is up to the standards that the Ministry demands (Ministry of Environment & Sustainable Development, 2013a). The guideline gives an outline for the report with all elements that need to be presented. It gives an impression of what elements are deemed important. In this chapter these elements are compared to the set-up of the initial framework, as presented in Part I.

7.5.1 Comparing the EIA guideline to the initial framework

In this paragraph, the elements of the EIA guideline for the construction of marinas are derived. Important to note however, is the phase(s) of a marina development that the guideline is aimed at. The guideline is about the environmental assessment of a proposed design for a marina. Here, the design phase has just been completed, following an inception and a development phase. The report then is about the site, the impacts on the environment the proposed development has and the measures to mitigate these impacts. Also, the EIA report will require an environmental monitoring plan and an environmental management plan for the given development, which indicates that impacts will be measured after construction and during use and operation, and the effectiveness of measures will be investigated. The considered phases in the EIA report are indicated in green in Figure 1.

This phase however, does not align with the focus of the initial framework, which focusses on the development phase of the marina project cycle, dealing with site selection and the broader environmental context. Going back to the EIA guideline, the introduction gives the relation between the EIA report and the development phase. The following is quoted from the preface: '[The EIA] encourages promoters to take into consideration environmental factors to ensure proper site selection at the very inception stage of a project proposal'. The guideline itself will 'assist proponents and consultants in the preparation of a comprehensive EIA document. It is by no means exhaustive, but provides the essential structure and the detailed requirements of the EIA report'.

So, the guideline is meant to encourage the developer to assess site selection and the environmental context of the project, in order to eliminate obstacles which may give rise to adverse environmental impacts that may be costly to mitigate or control. It aims to have project proponents deliver a 'proper' EIA report that fulfills the expectation and requirements of the Ministry of Environment for EIA licence assessment. This does apply to the phase that is meant pinpointed by the initial framework, and actually has a similar goal; the integration of the environmental context at an early stage of marina development, with subsequent site selection and marina type/size recommendations. This, like the initial framework, will aid the EIA licencing process.

The guideline prescribes a detailed structure and table of contents for the EIA report. Also, it gives a checklist that is used internally at the Ministry accept applications (not grant licences yet). The following points come forward in the EIA report in sequence:

- Introduction (summary; location, type/size marina, reference projects, benefits and opportunities),
- Policy, legal and administrative framework (compliance with relevant plans, policies, national laws, standards and regulations, and proof of land/sea ownership),
- Site description and environmental context,
- Description of existing base-line conditions (benchmark against which to measure environmental changes following implementation of the project),
- Project description,
 - General (type/size marina, layout),
 - Marine engineering aspects (dredging works, hard and soft coastal works, internal works),
 - Terrestrial engineering aspects (machinery, transportation, wastes),
 - Climate change issues (sea level rise, flooding),
 - Eco-friendly measures and sustainability (sustainable resource use, minimum energy use, climate friendly technology),
 - Traffic implications,
 - Other (work duration, capital investment).
- Categorisation and method for identification of environmental impacts (positive/negative, direct/indirect, recurring/non-recurring, reversible/irreversible impacts),
- Impacts and proposed mitigating measures,
 - Impacts during preparation phase (terrestrial and marine),
 - Impacts during construction phase (terrestrial and marine),
 - Impacts during operation phase (marine environment, water quality, solid waste, wastewater management),
 - General impacts (noise, storm water management, traffic implications, socio-economic impacts, visual, safety etc.).
- Public consultation (local public, stakeholders and communities),
- Alternatives (alternative solution to cause less harm to environment, including the 'no-development' option),
- Environmental monitoring plan and environmental management plan,
- Expertise of consultancy team (multi-disciplinarity, academic background, experience).

The EIA report, when carried out along the guidelines provided, delivers a good overview of the impact a certain marina proposal may have on its environment. To obtain an EIA licence, it is required to have investigated the environmental impacts, and indicated how these impacts will be dealt with in terms of mitigating measures, monitoring and management. The guideline triggers developers to take the environmental context in consideration whilst developing the marina proposal. It also urges proponents to consult the policy, legal and administrative framework and the public. Incomplete reports, not having followed the guideline or not adequately informed, may be subject to non-acceptance by the Ministry of Environment.

In comparison to the initial framework as proposed in Part I, similarities as well as differences can be found between the way a marina development process is proposed by the framework and how that is indirectly demanded by the EIA procedure. That on itself may well be the largest difference. Where in Mauritius no guideline or framework exists to aid in the process of coming from project initiation to a marina proposal, the Mauritian EIA guideline provides a checklist that needs to be adhered to. This will lead to an incomplete, narrow-minded assessment as focus lies on the negative impacts the marina imposes on the environment, the marina – environment link in isolation and potentially little coherence with a national coastal zone management plan. From Mauritian experience, this does not necessarily lead to an EIA licence guarantee. The initial framework however, provides a tool for a complete assessment of all potentially present Ecosystem Services versus potential marina features. It also starts with input from an ecosystem-based coastal zone management, which provides information on the coastal zone in its totality, of which the marina development a mere part is. It then delivers a proposal that has incorporated all information to create an EIA report, without much extra effort. Still, no guaranteed EIA licence can be expected, as this is purely up to the Ministry of Environment and the government, and public, to decide on.

Similarities are, evidently, the environmental scope of the development guideline. In the initial framework this aspect of the development cycle is focussed on as well, noting that parallel analyses will take place also. In the initial framework this ecosystem (services) analysis and evaluation will lead to location selection criteria, evaluation criteria and specific focus points, like vulnerable areas or potential complementing features. This adds to the traditional way of integrating the environment, that looks at the the environment less integrally, without considering the complete set of Ecosystem Services and the surrounding area.

Another similarity, although with a different focus, is the option of alternatives. Alternatives can be embodied by different types of a marina, different sizes and different locations. This is actively pursued and evaluated in the initial framework. The Mauritian EIA guideline also implicitly demands an alternatives evaluation. Strong point here, is the no-development option. This gives a perspective

to the findings of a preliminary marina proposal. This feature could enhance the initial framework. Of course, findings will still be theoretically discussed and only due monitoring will be able to deliver certainty. Congruent to this element, the description of the existing base-line condition is also a smart element to incorporate. It may make the monitoring results more valuable, and (adaptive) management more effective.

7.6 Conclusions

Throughout the comparisons in previous sections, some conclusions have been drawn. To be concise, they are listed below, complemented with other findings in this chapter.

On a coastal zone management level;

- The Mauritian ICZM strategy is an adapted version of the ICZM 'base-line' by Cicin-Sain *et al.*,
- The Mauritian ICZM strategy adapted along the lines, that are described in literature, by incorporating an ecosystem approach,
- However, despite the ecosystem approach, the Mauritian ICZM falls short in incorporating the ecosystem integrally into coastal zone management,

On the marina development level;

- There is no link to marina development in the ICZM strategy, no guidance document for marina development, no sustainable approach to marina development,
- There are two documents considering marina development in Mauritius;
 - 'marina design guideline'; providing basic consideration to the design stages of marina development. Provides no added value over other available guidelines online, There is no reference made to the Mauritian context (legislative, political, economic)
 - 'EIA guideline for marinas'; this guideline guides the writing of an EIA for marina proposals; it does not guide the development of a marina proposal.
- Although the initial framework and the Mauritian documents do not present a comparable guideline, they do consider the same stage of marina development.
- The EIA guideline naturally refers to the impact the marina has on its natural environment. The EIA report therefore solely considers what impacts there are on the natural environment and how these are mitigated or negated. Neither of the documents incorporates the ecosystem integrity, the reciprocity between a marina and its environment or the set of Ecosystem Services the ecosystem provides.
- The Mauritian EIA guideline included a requirement for the alternatives evaluation; the inclusion of a 'no development' option. This was missing in the initial framework and will be included for the case study and framework enhancement cycle.
- All items required for an EIA report, are products of the initial framework. This means the EIA procedure can be completed (licence granted or not).
- Lastly, the EIA guideline can be adopted in the ecosystem-based coastal zone management plan, as a licence on environmental grounds is still required for any coastal development. EIA procedures however, will be incorporated in the framework for sustainable marina

development, by introducing it at the initial stage of marina development, and providing feedback information from marina designs to the ecosystem-based coastal zone management. This link is given by the flow chart arrow from 'EIA & licensing' to 'Ecosystem-based coastal zone management plan'.

Part III. Case study Mauritius & Framework enhancement

Part III presents the greater part of this report. It presents the application of the initial framework to a case in Mauritius, with a preliminary sustainable marina concept as a result. More importantly, the framework has been improved by lessons learned during the case study. An improved integration of stakeholders, a more workable ecosystem assessment and other improvements are collected in the final chapter of this Part, Chapter 11. Earlier chapters discuss general information about Mauritius (Chapter 0), and, naturally, the different stages of the case study in Chapter 9.

8. Mauritius general information

The Republic of Mauritius is an independent island nation in the Indian Ocean. It is formed by the island of Mauritius, the island of Rodrigues and outer islands Agalega and St. Brandon. The island of Mauritius, the main island of the republic, is located 1,000 km east of Madagascar and 2,000 km east of the African mainland, see Figure 7. At latitude 20° S, the island experiences a tropical climate, modified by tradewinds from a south-east direction throughout the year. The island has a total land area of about 2,000 km², and an Economic Exclusive Zone (EEZ) of 2 mln km². The island is surrounded by more than 150 km of white sandy beaches and the lagoons are protected from the open sea by the world's third largest coral reef, which surrounds most of the island. Other coastal types include rocky shores, muddy shores and cliffs. Just off the Mauritian coast lie some 49 uninhabited islands and islets, some of them are used as natural reserves for the protection of endangered species.

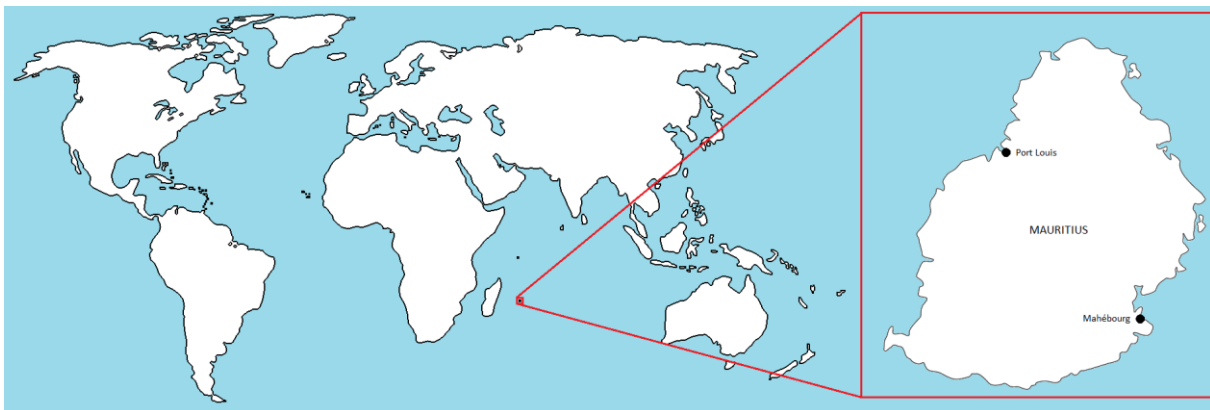


Figure 7 - Geographical location of Mauritius

Mauritius knows a rich history of population movements in the 18th, 19th and early 20th centuries, resulting in a unique blend of different races, cultures and religions. People of European, African, Indian and Chinese origins have created a multiracial society where the various cultures and traditions flourish in peace and harmony. The Dutch Republic colonized the island in 1638 and gave the island its name after Prince Maurice van Nassau. The Dutch imported sugar cane to the island from Java, the type of sugar cane that – until recently – has been of great importance to the island's economy. Important in relation to the marina industry is to know that the Republic of Mauritius has been diversifying their export markets, to cope with the decline in sugar exports. ICT, textiles and tourism are now main economic pillars. The Dutch exported the island's ebony wood, and are held responsible for the extinction of the Dodo (Hume *et al.*, 2008). The Dutch left the island in 1710, after which the French took over in 1715. They took colonization a step further and the island became an important base on many trade routes from Europe to the Far East. In 1810, the English forcefully took over the reign on the island. The island's economy picked through extensive sugar production.

Another event that resulted in the current multi-ethnic character has been the abolishment of slavery by the English. Instead, the English employed cheap labour forces from India and later, China. In 1968 the island gained independency and joined the Commonwealth of Nations in 1992. The population of the island reached over 1.25 mln people in 2015, growing at a rate of 0.4% each year (UN, 2015).

As stated, the Mauritian population offers a unique blend of cultures and origins. This can be seen in Mauritian daily routines, but a few notions arose from the author's site visit. These are fairly generalised notions, but are of importance for the marina industry and as such, for the case study in this report. First to note, the governmental parties are mainly run by people of Indian origin. This has grown historically, with large numbers of Indians being brought in by the English from 1834 onwards. The independency of Mauritius has been initiated and orchestrated by three Indians. Strong diplomatic, economic and even military relations have been established with India since. The link to marina development is the notion that Indian people, both in India as well as in Mauritius, generally have little affection with, or experience with, marinas. From author's experiences from local interviews, the relation between (high-end) tourism and marinas, socio-economic development and marinas or the value of boating in general is not well understood. Due to this, political reasons are partly to be held responsible for the lack of marina development in Mauritius.

Second to note, the larger part of the Mauritian's economy descends from, and is maintained by, European entities. Originating from the sugar cane industry, roughly five 'trade houses' or families control a large part of all economic activities across most sectors, having diversified along the country's diversification of economic pillars. For example, in the tourism sector, many hotels and resorts are allied to the 'trade houses'. These entities are also expected to be of importance for any marina development in Mauritius. Historical marina proposals for Port Louis (Les Salines, Trou Fanfaron) and Petite Rivière Noire are initiated by the different trade houses (i.e. Le Suffren Group, Rogers Group). The La Balise Marina has been promoted by the Espitalier-Noël family, a family that has been involved in sugarcane cultivation for two centuries. To show the extent of these groups, the ENL Group (Espitalier-Noël Group) represents one of the biggest conglomerates in the country, with assets worth Rs 48.4 billion (June 2015), employing 6,800 people across 150 companies. The ENL Group holds five divisions, ENL Property, ENL Commercial, ENL Investment, ENL Lifestyle and ENL Agribusiness (source: www.enl.mu, 9/2016). The same characteristics hold for the other main trade houses. From author's experience, the commercial drive to develop marinas is well present in Mauritius. The trade houses have the means to realize a project, aided by the favourable investment climate present in Mauritius (BOI, 2013).

8.1 Environmental characteristics of Mauritius

8.1.1 Climate and oceanography

Mauritius is located at 20°S and 57°E, and therewith lies in the tropical climate band, close to the subtropical zone (below 23°S). It enjoys a (sub)tropical climate with rather cool winters from May to November with mean temperatures during Southern Hemisphere winter ranging from 23°C peaking at 34°C over the coastal areas. Mean lows of 22°C to 16°C have been recorded in the summer months. On average, seawater temperatures range from 23°C to 29°C.

The area is dominated by south eastern tradewinds with average speeds during the summer months of around 13 km/h reaching 20 km/h during winter months, with days of considerably stronger winds being experienced throughout the year as a result of storms generated in the Southern Ocean during the winter and cyclones during the summer months. Cyclones occur around once a year on average, with varying intensities, approaching the island anywhere from the North West to East (300° – 90°), See Figure 8 and Figure 9. The season for tropical cyclones in Mauritius is from December to March, with peak activity occurring during January and February.

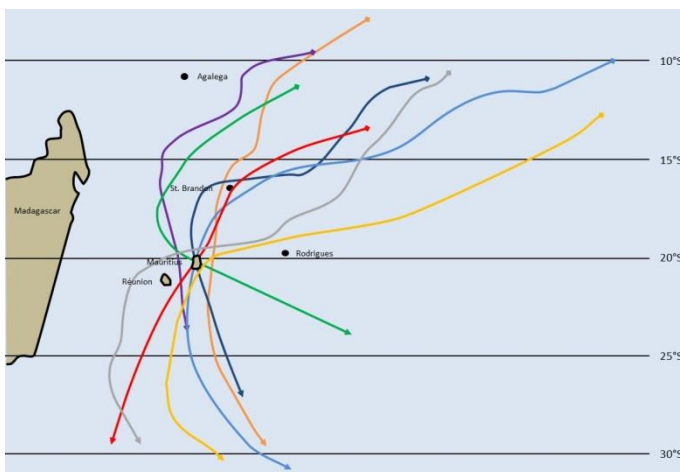


Figure 8 - Cyclone tracks passing over/by Mauritius 1982 - 2005 (source: Mauritius Meteorological Services)

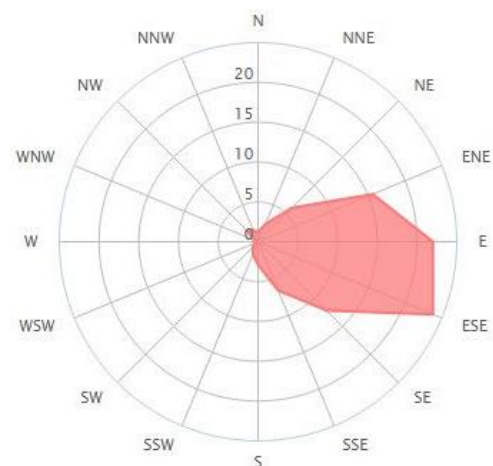


Figure 9 - Wind rose, distribution of wind direction at Plaisance airport [%] (source: Mauritius Meteorological Services)

Mauritius is located within the South Equatorial current. This current system is driven by the prevailing South-Easterly tradewinds and is essentially an elliptical counter-clockwise water circulation between the Australian West coast and the East coast of Madagascar. It influences the near shore current pattern and to a smaller extent the current flows inside the lagoons. Currents inside the lagoons are dominated by tidal flows and river discharges.

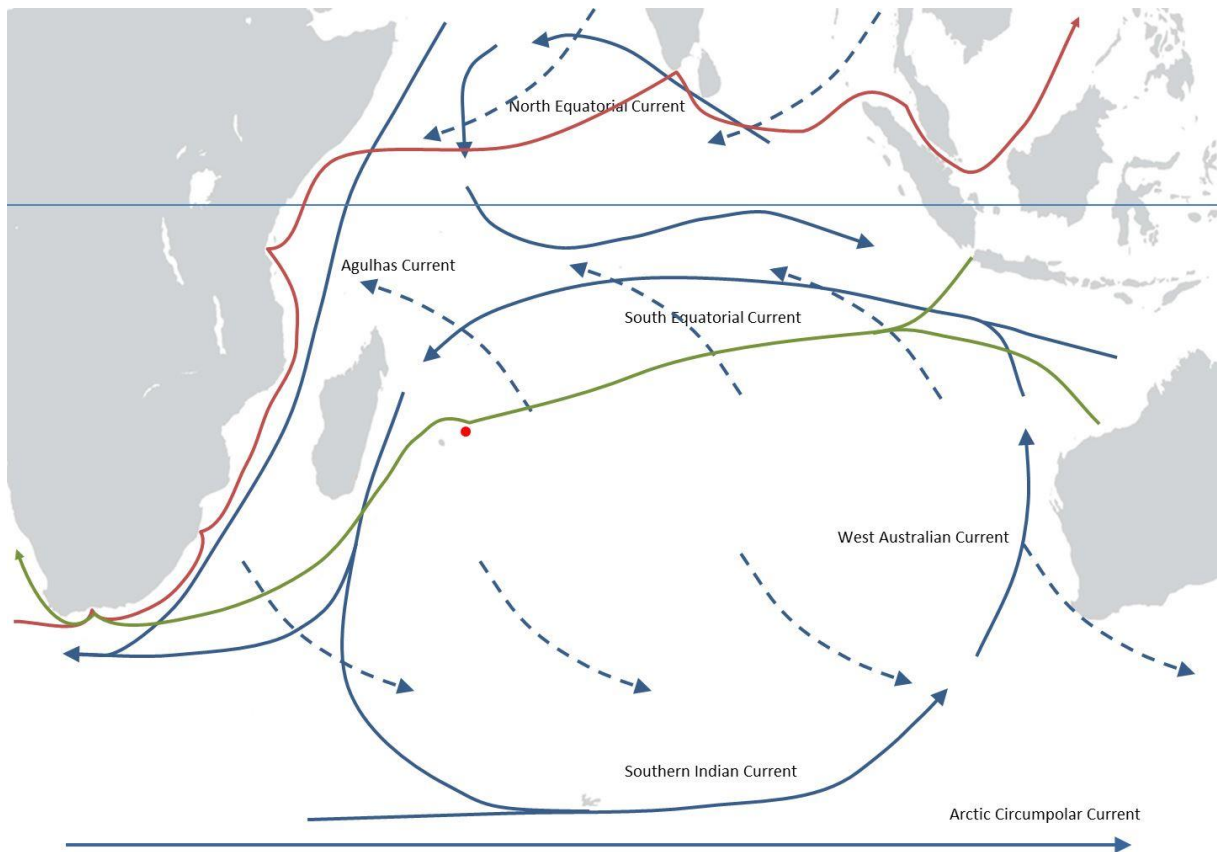


Figure 10 - Indian Ocean currents, winds and routes (source: Google, Wikipedia)

The combination of trade winds (dashed blue) and the equatorial current (solid blue) explain why the traditional sailing route (green) traces by Mauritius (red dot in Figure 10). Sailing yachts normally travel from Australia or Asia to Capetown, and have the Republic of Mauritius as a first stop along the way, after a long leg of sailing. This has been confirmed by the interviews held among round-the-globe sailors visiting Rodrigues. The opposite route from Africa to Asia is a more northerly route (red), hugging the coast and avoiding the South Equatorial Current.

8.1.2 Natural disasters, climate change and sea level rise

Mauritius is naturally prone to the disasters resulting from oceanographic processes and climatic phenomena, as introduced in the previous section. Cyclone impacts may include sea surges, severe wave attack and barometric pressure reduction (with further water level set-up as a consequence). Mauritius has a sophisticated system of precautions, combining a network of cyclone shelters with education, a good early warning system and mandatory closings of businesses and schools when a storm threatens (Mauritius Meteorological Services, 2008). During tropical cyclone Gamede, February 2007, 'only' two people got killed by rainfall flooding.



Figure 11 - Warning sign for flooding
(Photo courtesy: Gosse de Boer)



Figure 12 - Flooding in Port Louis, 2013 (Photo courtesy: Clever Dodo)

With predicted increase in cyclonic disturbances and storm surges, coastal Mauritius looks extremely vulnerable; elevated sea levels will be experienced more frequently in many coastal locations in the future, with low lying areas particularly vulnerable to flooding under these circumstances (Baird, 2003). Sea level rise has been between 10 and 20 cm over the 20th century, and the IPCC (Intergovernmental Panel on Climate Change) predicts a range of 9 to 88 cm sea level rise for the 21st century. Baird and associates (2003) predict a total rise of around 12 cm for this century, extrapolating the current 1.2 mm/year. The latter number, 1.2 mm/year will be incorporated in the case study, this number has been adopted in Mauritian ICZM policy as well.

Another aspect of climate change is the expected rise of sea surface temperature. According to National Oceanic and Atmospheric Administration (NOAA) sea level has risen significantly over the last decades and is expected to continue its rising trend (NOAA, 2016). This is of importance for coral reef growth and biodiversity.

8.2 The coastal environment of Mauritius

8.2.1 Hydrodynamic processes

Tides

The tides in Mauritius are a weak mixed semi-diurnal system with a neap range of 0.3 m and a spring range 0.5 m. The range between the Highest Astronomical Tide (HAT) and the Lowest Astronomical Tide (LAT) is in the order 0.8 m (Baird, 2003; Mauritius Meteorological Services, 2008). This information aligns with the information given on British Admiralty Chart no. 711 for the tidal range in Port Louis, Mauritius;

Table 5 - Tide levels (British admiralty chart no. 711, 2012)

HAT	MHWS	MHWN	MLWN	MLWS	LAT
0.8 m	0.7 m	0.5 m	0.4 m	0.2 m	CD

Tidal fluctuations are influenced by the 'Inverse Barometric Effect' during cyclonic conditions, potentially a 1 cm rise in sea level for each 1.00 mB of depression. The values in Table 5 are adopted for case study purposes.

Waves

Despite the predominance of southeast tradewinds in Mauritius, the major wave-generating systems resulting in large wave conditions are due to the passage of cold fronts with their associated low pressure systems that pass to the south of the African continent.

During summer, the hot season, the situation becomes a little more complex: the trade wind circulation becomes less regular and convective instability develops. In this season, depression and tropical cyclones spawn in the southern equatorial belt of the Indian Ocean, around 5 – 15°S (see Figure 8). The cyclones generally curve southward and east just prior to reaching the island of Mauritius. Cyclone intensity typically diminishes with latitude (Baird, 2003).

As a result of the above climatic influences, the waves affecting the Mauritian coastal areas may be generated through several different meteorological phenomena (ASCLME, 2012a):

1. Local generated seas. Waves may be generated in the immediate vicinity of Mauritius by the southeast tradewinds. These waves in open sea are between 0.5 m during summer and 3 m during the winter with a period of 3 – 11 s.
2. Southern Hemisphere swells. Mauritius is strongly influenced by swells generated in the Southern Ocean due to passing extratropical cyclones. The swells typically approach Mauritius from the southeast to southwest directions (135° – 225°). Wave period increases

significantly as these waves travel. Wave characteristics are 3 – 5 m in height, with a wave period of 12 – 20 s. The swells are more persistent during the transition and winter months.

3. Tropical cyclones. As noted before, tropical cyclones approach Mauritius from northwest to eastern directions (300° – 90°). Tropical cyclones can have very high wind speeds and large waves, with peak significant wave heights in excess of 15 m not being uncommon. High wind speeds and low depression cause sea level to rise as well.

In a coastal erosion study, Baird and associates (2003) have simulated the wind conditions and derived design wave conditions for Mauritius by a statistical extreme value analysis. Input for the study has been a set of twenty-five historical cyclones. The cyclones were simulated in the WAVAD model. The design wave condition is valid around Mauritius, but mainly at the northern half, which gets direct impact from cyclones (see Figure 8 and Figure 13). The wave conditions have been translated to the 30 m depth contour.

Table 6 - Design wave conditions Mauritius (Baird, 2003)

Return period [yrs]	Surge [m]	Hm0 [m]	Tp [s]
5	0.16	11.8	14
10	0.24	14.2	16
25	0.33	17.2	17
250	0.43	19.8	19
100	0.54	22.0	20

Table 6 presents large wave characteristics to adhere to. An important notion to emphasize is that these values correspond to wave characteristics at the 30m depth contour. Due to the island’s coastal geomorphology, with continental flats, islands, coral reefs, shallow lagoons and cliffs, these waves are attenuated in a large way. The rate of attenuation needs to be assessed for specific areas around the island.

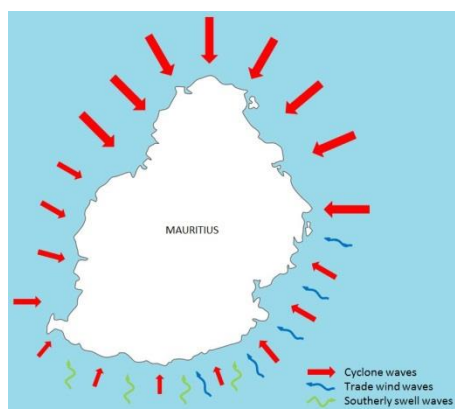


Figure 13 - Wave type and direction Mauritius (adapted from Landell Mills, 2010)

Current

Although there are some large current systems in the South Western Indian Ocean, they have little effect in the Mauritian coastal waters. Currents inside the bays are driven by wind, tides and are patterned by bathymetry and the geometry of bays and lagoons. At places where rivers discharge into lagoons, larger currents can be witnessed, especially during periods of heavy rain. These rain-induced currents quickly disperse in open water of bays or lagoons, but can be heavy in deltaic areas. Currents in the bays and lagoons do not exceed 1 m/s, by rough estimates of Baird and associates (2003). Also, in different EIA statements of past coastal development proposals, measurements have shown only weak currents. These currents are, however, very important to the lagoon and bay's ecosystems. It provides a link between different ecotypes, transporting nutrients, seedlings, algae and other elements around the area. Disturbing or altering these current flows, may impact parts of the ecosystem heavily.

8.2.2 Coastal geomorphology

Significant features of the coastal geomorphology of the island of Mauritius are the lagoons, cliffs and islets and the channels that cut through the lagoon reefs. The coastal zone also includes bays (13.6 m²), estuaries and salt marshes (132 km²). There are approximately 300 km² of lagoons with fringing reefs in Mauritius, with a significant barrier reef in the South West, see Figure 15 (Baird, 2003; Landell Mills, 2010). The lagoons are naturally separated by the influx of major rivers, which limit the extent of the coral reef, see Figure 16.



Figure 14 - Aerial view of fringing reef
(Photo courtesy: Gosse de Boer)

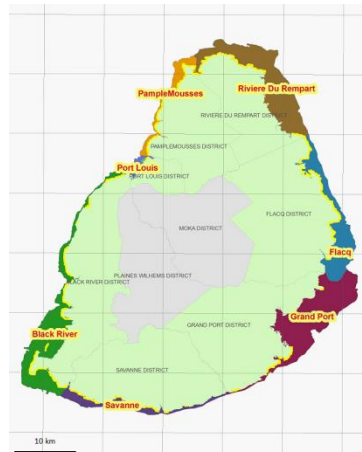


Figure 15 - Lagoon area, divided
by region (Landell Mills, 2010)

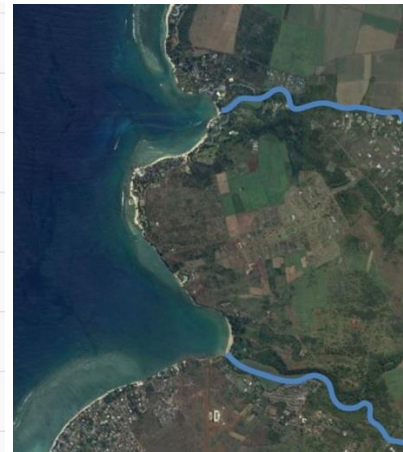


Figure 16 - Reef intersected by river
flow (source: Google Earth)

Coral reefs surround most of the Mauritian coastline, with regular natural openings due to (historic) water flows. Exceptions are the coastlines off sea cliffs along the South coast and near Pte Moyenne, adjacent to Albion (just south of Port Louis), and the mudflats on the South East coast near Mahébourg.

The lagoon

As to be seen from Figure 15, lagoons form much of the coastline of Mauritius. The lagoons are typically sandy bottomed, bounded on the seaward edge by a fringing reef, with an algal ridge. On the landward edge the lagoon is bordered by coral sand beaches and low lying dunes. These dunes have, in many cases, a narrow back dune wetland draining the slope that rises up to the central plateau.

The lagoon is generally made up of different zones (see Figure 17), which will be shortly elaborated;

- Foreshore,
- Nearshore,
- Mid-lagoon,
- Back reef,
- Reef crest or algal ridge,
- Fore reef.

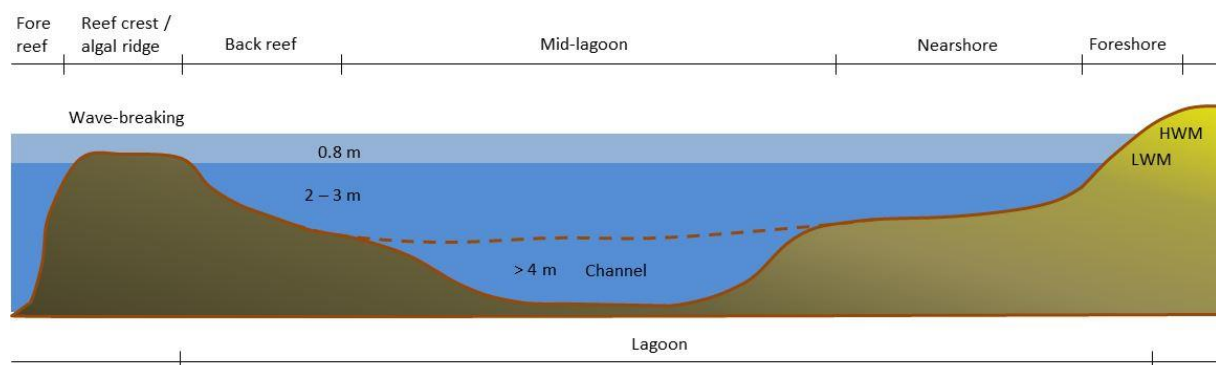


Figure 17 - Schematic cross-section Mauritian lagoon

The foreshore comprises the high water mark (HWM) zone to the low water mark zone (LWM) and is part of the sand dune zone. Above the HWM, dunes are formed generally by wind-blown action of sand. Dunes around the coast of Mauritius have been greatly exploited over the last century; sand dunes have been excavated for the sand resources and flattened to accommodate development.

The nearshore comprises the low water mark (LWM) to the mid-lagoon zone. Generally this zones form one entity because it is in the same dynamic zone. Wave climate has an important role in the type of sediment and colonization of sea grass or coral.

The lagoon extends from the near shore to the reef flat. This can be further subdivided, depending on the size of the lagoon, into shore reef zone and back reef zone. Most lagoons in Mauritius do not exceed the depth of 2 m at average tide except where channels are present. Some lagoons however, like at Mont Choisy and Belle-Mare are naturally deep and depth may attain 3 – 4 m. Deep channels

are present in the region of Mahébourg, Black River and on the north east of Mauritius. Bays, like Blue Bay and Grand Baie are generally deeper. Most lagoons are colonized with corals (Acropora type mostly).

The reefs of the lagoons are located as far as 4.5 km offshore along the windward East coast and near to shore on the leeward West coast.

The back reef extends from the foot of the reef flat along an almost regular gradient. The mid lagoon and back reef zones are sometimes distinguished by depth features, mid-lagoons being generally deeper than the back reef. Back reef colonies of coral and biodiversity tend to be more diverse than mid-lagoon communities.

The reef crest is found at the seaward end of the lagoon, where waves break before entering the lagoon. The crest is normally exposed at low tide and bears full wave attack forces. The structure of the reef crest is often found to be rough, and traversed by deep grooves, or channels, that help mitigate the force of incoming waves.

The fore reef presents the transition between the reef crest and the continental shelf. The zone is also called the buttress zone, often complexly structured with buttresses, deep grooves and sudden depth increases. At larger depths, reef-building corals become sparse due to light limitation.

Rocky shores and cliffs

At several stretches of the Mauritian coastline, rocky shores and cliffs are present. These stretches are found at the southern shore of Mauritius and on the western shore between Albion and Flic & Flac. Generally, no reefs or lagoons are present and heavy seas impact the shoreline, attenuated only by natural rock revetment at the base of cliffs. Over time, this has led to rugged, steep, rocky shores. Some pocket beaches may form within natural coves formed as a result of natural erosion of cliffs.

8.2.3 Coastal ecosystems and biodiversity

The following figure, Figure 18, depicts an overview of the coastal ecosystem of the same order of scale that is used for ecosystem-based management of the coastal zone of Mauritius. It includes a range of human activities like agriculture, urbanization, coastal development, recreation and transportation. It also shows the marine part of the ecosystem, with mangroves and dunes on the foreshores, lagoons with seagrasses and recreational and commercial activity, the coral reef and the connection to the larger scale ecosystem, the open ocean.

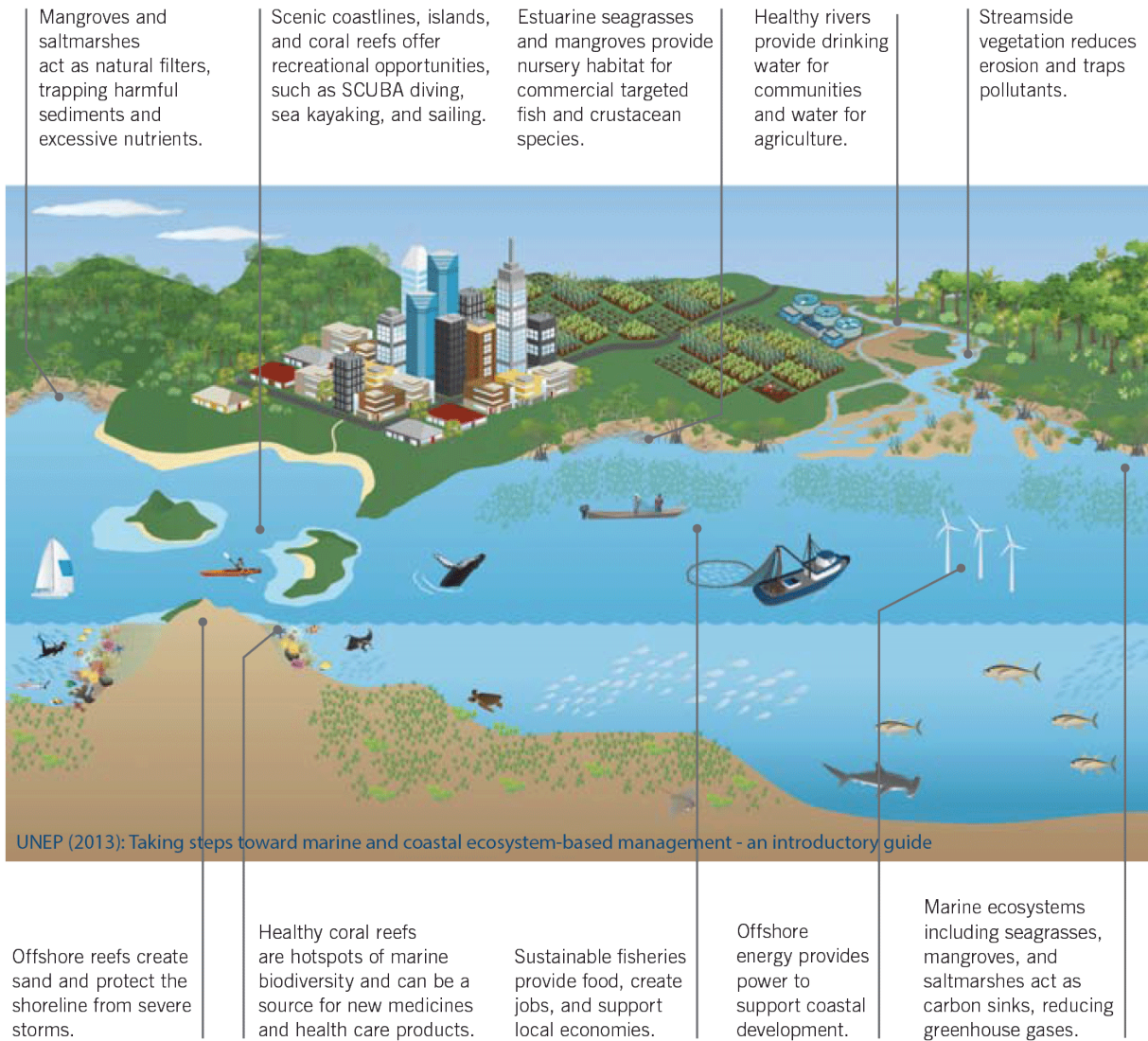


Figure 18 - Coastal ecosystem (source: UNEP, 2013)

This coastal ecosystem comprises of different smaller scale ecosystems, like the mangroves, seagrasses and coral reefs. All of which are well represented in Mauritian coastal area. These three ecosystems are shortly discussed below.

Coral reefs

According to analysis of the reefs of Mauritius by Baird and associates in 2003, the reefs are characterized as 'catch-up reefs'; reefs that are still trying to establish a reef front at sea level after being submerged during the Holocene era. Also, in a global context, the reefs are found at the southernmost extremity in the Western Indian Ocean. Water temperature ranges from 20 °C to 27 °C, which are below optimum temperatures for coral growth of about 30 °C. Sea surface temperature increase therefore will not pose risk to coral growth and/or bleaching in the near decades (Baird, 2003; Landell Mills, 2010).

There are five types of reef to be found around the Mascarene islands: fringing reefs, patch reefs, atolls, reef flats and barrier reefs. Fringing reefs occur in shallow waters near to land, and most of the reefs around Mauritius are of this type. They encircle Mauritius and protect the coastline from the sea by attenuating waves, supplying sediment and delivering habitat. Patch reefs are found in relatively shallow waters around Mauritius where the underlying seabed has been close enough to the surface for corals to grow. Atolls are only found at offshore islands of the Mauritius, like St. Brandon and Agalega. Reef flats do not occur around the island of Mauritius either, but are encountered around Rodrigues. Barrier reefs are developed typically on the edge of a continental shelf, usually far from the main shoreline and separated by broad and deep waters. These occur in the South East of the island (ASCLME, 2012a).

The coral reef habitats around Mauritius are being degraded due to a combination of factors such as excessive growth of algae due to nutrient levels (sewage and fertilisers), land-based sedimentation and extensive coastal development. Locally, anchoring and fishery has impacted the coral reefs heavily (Ministry of Environment & Sustainable Development, 2011).

Healthy coral reefs foster species diversity. Fungi, sponges, molluscs, oysters, clams, crabs, shrimps, sea urchins, turtles, and many fish seek food and shelter amid reefs. The architecture of corals provides reef fish protection from carnivorous species such as sharks and barracudas. Sea cucumbers, worms and molluscs burrow into the reef-generated sand to hide from their enemies.

Mangroves

Mangroves in Mauritius play an important role in the coastal ecosystem by providing habitats and nursery grounds for crabs, shrimp and juvenile fish, as well as providing substrata for fixation of oyster spat. Mangroves were once abundant on the shoreline of Mauritius, but large areas have been lost, with a 30% reduction between 1978 and 1994. This has been linked to overharvesting for timber, firewood and for tourism development (ASCLME, 2012b). In the 2011 Environment Outlook Report for Mauritius, the constant pressure exerted on this ecosystem is being recognized, and a mangrove propagation programme was initiated in 1995 by the Fisheries Division. To date of the

report, the total mangrove cover stands at 145 ha. Also, the mangroves are protected species under the Fisheries and Marine Resources Act 2007 (Ministry of Environment & Sustainable Development, 2011).

Seagrasses

Extensive and important seagrass beds in lagoons surrounding Mauritius were reported prior to 1980; however, current data on the status of seagrass habitats is lacking and their status is assumed to be declining. Seagrasses are also threatened by the high use of fertilizers in sugar cane agriculture, and specifically by the eutrophication of coastal lagoons that is caused nutrients leach into these shallow areas. In addition, seagrass beds are being dredged and destroyed to provide bathing and other tourist facilities (ASCLME, 2012b).

There are some areas of vibrant seagrass habitat, notably the area of lagoon adjacent to Les Salines, between the estuaries of Grande Rivière Noire and Petite Rivière Noire which continues down to the lagoon of Île aux Bénitiers, in the South West (Landell Mills, 2010).

8.2.4 Mauritian eco-regions

The Mauritian coastline knows a wide variety of coastal types. Based on the environmental and geological features of the coast, the coastline can be subdivided in coastal 'eco-regions'. These are regions where the same features exist, and where ecosystems are similar. For example, a wide lagoon with coral reefs represents an entirely different eco-region than a rocky coast with steep bottom slopes and no reef.

According to the World Wildlife Fund (WWF) classification for ecoregions, the definition of an ecoregion is as follows, and applied in this research study as shown in (World Wildlife Fund, 2016);

Eco-region: 'A large area of land or water that contains a geographically distinct assemblage of natural communities that: a) Share a large majority of their species and ecological dynamics, b) Share similar environmental conditions, and, c) Interact ecologically in ways that are critical for their long-term persistence.'

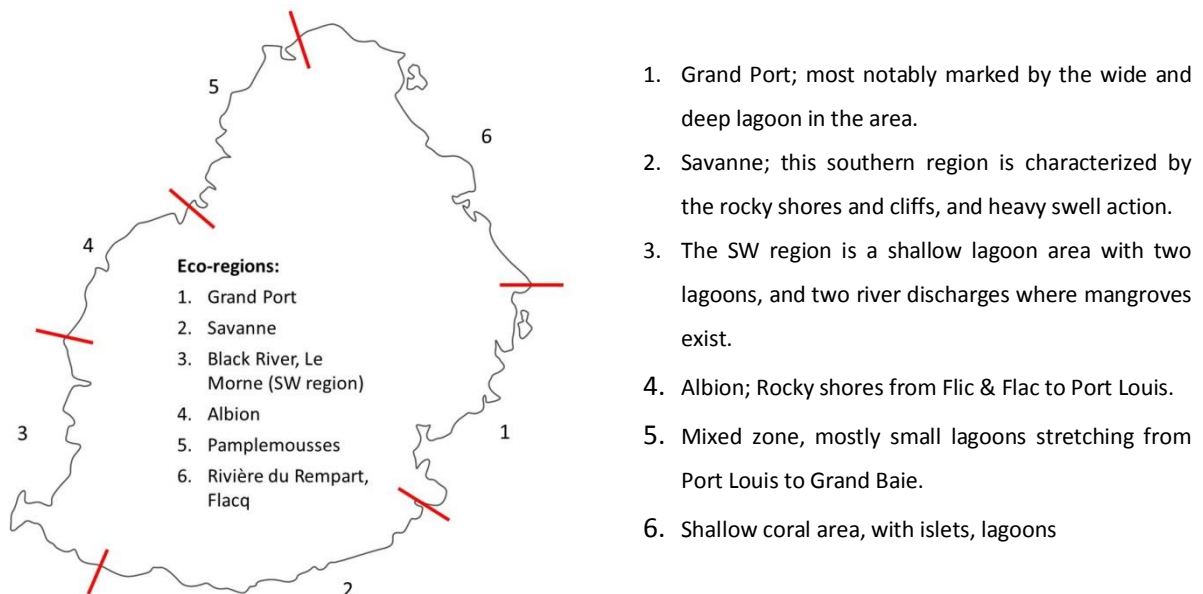


Figure 19 - Mauritian eco-regions

above depicts the different eco-regions and states the main features. These eco-regions are used by the ecosystem-based management plan to base their management decisions on, whilst realising cross-region relations.

8.2.5 Marine Protected Areas and Environmentally Sensitive Areas

In Mauritius, several areas are assigned to be a Marine Protected Area (MPA), a fishing reserve or a marine park. Although large variations of MPAs are included, MPAs are clearly defined geographical marine areas that are more strictly regulated in terms of exploitation, use, and other human activities. The goal of appointing these areas usually is the long-term conservation of nature with associated Ecosystem Services and cultural values. Fishing reserves are a kind of a marine protected area, in a sense that in these area restrictions apply with the purpose of creating grounds for fish reproduction, habitat and biodiversity. In Mauritius the following areas have been appointed (see Table 7);

Table 7 - Marine Protected Areas Mauritius (source: Ministry of Fisheries, 2016)

Marine Protected Area	Area (ha)
Blue Bay Marine Park	353
Balaclava Marine Park	485
Poste Lafayette Fishing Reserve	280
Poudre d'Or Fishing Reserve	2542
Trou d'Eau Douce Fishing Reserve	574
Port Louis Fishing Reserve	331
Grand Port Mahébourg Fishing Reserve	1828
Rivière Noire Fishing Reserve	797

Besides the officially recognized and managed MPAs, studies have been conducted to map environmentally sensitive areas (ESAs) around Mauritius. These areas have been earmarked for their ecosystems, endangered or endemic flora and/or fauna, historic natural or cultural values or a combination thereof. A complete study has been executed in 2007 on behalf of the Mauritian government, in light of the island's sustainability goals (Maurice Île Durable, Integrated Coastal Zone Management and others). However, this study is not publicly available and has not been used in this report. The ICZM Framework report does use the report and through this report, information on environmentally sensitive areas has been obtained indirectly.

In Mauritius, legal restrictions to human activities apply in the designated marine protection areas. Fishing, for example, is not allowed and a no-take policy is adhered to. Also, anchoring of yachts or boats is not permitted, fearing damage to seabed and species by anchors. The restrictions do not forbid any leisure activities like scuba diving, swimming, snorkelling and/or sailing, but does require a fee to be paid for undertaking such activities.

For the Balaclava and Blue Bay areas, restrictions apply to any structural and/or permanent development in the coastal area. This makes marina development an impossible development for these areas.

Concluding this section, designated natural areas are important for the continuity and health of coastal ecosystems, much like their terrestrial counterparts. Coastal ecosystems benefit from the shelter, habitat, feeding and nursing grounds the areas provide. As such, these areas have high aesthetic and biodiversity value and may attract eco-tourists. Marina development can play into this, by providing the boating and mooring facilities. A marina however, cannot be built in such designated area for legal reasons.

8.3 The socio-economic characteristics of the Mauritian coastal zone

The Mauritian coastal zone, with its coastal features, is rich in natural resources and wildlife. The coastal zone supports a large proportion of the population and economic activities. Economic activities in the coastal zone include recreation, tourism, fisheries, trade and industry. According to the national statistics, approximately 20% of the population are resident in the coastal areas.

The Financial Strategies Report of the ICZM Framework (Landell Mills, 2010) estimated the revenue directly generated from the coastal zone as just under Rs 74 billion³, equivalent to 36% of GDP. 99% of this amount is generated by tourism activities.

Besides the income provided by the coastal zone through tourism and fisheries, the coastal zone also provides a natural protection from natural forces from the ocean (i.e. wave action, storm surges, sea level rise etc.). Observed erosion and degradation of the coastal ecosystem threaten the viability of the major economic activity and protective functions. It can be concluded that vitality, aesthetics and ecological functioning of the coastal ecosystems are vital for the sustainability of socio-economic characteristics.

To specify the economic activities, the most common activities are fishery and tourism-related activities. Fishery is done by artisanal fishery, being small-scale, low-technology, low-capital fishing practices undertaken by individual fishing parties (non-commercial). Their produce is usually not processed and is mainly for local consumption. Tourism activity involves a wider range of activities, like scuba diving, glass bottom boating, snorkelling, whale/dolphin-watching, water skiing and cruising trips. More importantly, beach use, bathing areas and coastal tourism development like hotels and resorts, make large use of coastal resources.

As acknowledged in national policy and independent reports on the matter, the absence of proper coastal zone management, the intensifying pressure from tourism and leisure activities, human settlements and onshore activities, are degrading the coastal zone, limiting its ecological integrity and protective function. The named impacts threaten the potential of the coastal zone to be able to sustain socio-economic activities in the long-term.

In terms of a potential marina development, there are large socio-economic benefits to be obtained by a marina development. Directly, through job creation by tourism activity and marina staff or support. And indirectly, by the added value to the area, attracting economic activity, tourism and resources. However, a marina development can have an impact on its surroundings like any other coastal development. Consideration of both is of large importance to achieve sustainability.

³ Excluding port revenue

9. Mauritian development strategies

In Mauritius, a lot of attention and effort is going to becoming an exemplary 'green' and sustainable small island developing state (SIDS). With support from large organizations like UNEP, UNESCO and the Indian Ocean Commission (IOC) among others, recommendations, plans and strategies have been developed. A dedicated division of the Ministry of Environment, the Sustainable Development Division, seeks to streamline findings, recommendations and goals into national policy. In fact, the Integrated Coastal Zone Management Framework is also a product of this national priority. In broadest terms, the national policy on sustainable development is covered by the Maurice Île Durable (MID) project (Ministry of Environment & Sustainable Development, 2013b). In terms of sustainable coastal development, the Ocean Economy strategy and the Mauritius Sector Strategy plan on Tourism apply.

1. Maurice Île Durable

MID is a societal project that represents the objective to achieve sustainable growth, with a vision for Mauritius to become a model of sustainable development. The MID process rests on five pillars, represent by the five E's; Energy, Environment, Employment/Economy, Education, Equity. For each 'E', a goal has been set. For Environment, the goal has been set as follows; 'to ensure sound environmental management and sustainability of our Ecosystem Services'. Together with the goal of Employment/Economy – 'to green the economy with decent jobs, offering long-term career prospects', a sustainable marina development could become an integral part of the MID project.

2. Ocean Economy

The Ocean Economy strategy acknowledges the vast area of the Mauritian Exclusive Economic Zone and the large potential of natural resources. It seeks to sustainably exploit the oceanic territory for economic growth. Not only the deep ocean territory but also the marine coastal areas are considered. In the Ocean Economy Roadmap (Prime Minister's Office, 2013), several clusters are identified. For the cluster of 'Marine Services', an enormous business opportunity is acknowledged for the Marine Tourism and Leisure segment, foreseeing the quadrupling of the segment's GDP contribution to Rs 5.2 billion in 2025. Specifically, a marina industry is being named as a priority. The Ocean Economy strategy therefore offers a good platform to introduce a marina development within its sustainable development objectives, aligning with other national policies.

3. Mauritius Sector Strategy on Tourism

In the Mauritian Tourism Strategy plan 2015 – 2020, the need to sustainably develop the Mauritius' tourism sector drives a series of improvements and priorities for the (near) future. Environmental

health, sustainable coastal zone management, promotion of eco-tourism and responsible tourism are pin-pointed as important aspects to achieve sustainable tourism growth. The enormous growth of the tourism sector over the last decade has made the sector an important economic pillar for Mauritius. This growth is both expected and hoped to grow, but according to national policy, only on a sustainable basis.

Summarizing the relevant national policies, the collective has pinpointed reaching sustainability as a high priority for the country. Although this applies to all sectors and types of development, the coastal zone represents a large portion of the country's social and economic well-being and development. Sustainable growth includes continuous economic development, while respecting the limits of natural resources. Marina development has been acknowledged as an underdeveloped sector of the marine tourism and leisure branch. The potential for socio-economic benefits, both on short- and long-term of marina development, is huge. However, like any other coastal development, the risk exists that a marina development makes use of coastal resources in an unsustainable manner. To achieve sustainable growth through marina development, a sustainable marina needs to be developed, adhering to a sustainable coastal zone management plan at the scale of the coastal zone. From national projects like the MID, funds and political willing are available to assist and aid in the development of a sustainable marina.

10. Case study of the initial framework in Mauritius

This chapter will relate the theoretical framework and ecosystem-based coastal zone management plan to the marina development practice. Applying the framework for Mauritius, delivers insight on its effectiveness, shortcomings and on the way future marina proposals could be given shape in the island context. The insights will help to enhance the framework, making it more applicable and synchronized with practice.

In the previous chapters, the Mauritian context has been described. Its coastal features, marine ecosystems and socio-economic aspects have been elaborated. This information serves as input for the framework, together with an initiative plan, an ecosystem-based coastal zone management plan and a set of stakeholders, holding an interest in coastal development, and marina development in particular.

This chapter is structured like the framework is structured. Section 10.1 deals with the initiation phase as shown in the initial framework in Part I and Figure 20 below. Section 10.2 takes all information from the initiation phase and general information about coastal Mauritius from previous chapters. The framework results, after different analyses and evaluation, in the preliminary sustainable marina proposal. This is the first goal the framework is aimed at achieving, as following design practices already know guidelines and sustainability considerations (refer to Part 0).

To increase case study structure, each chapter will start with a picture of the framework, highlighting the step considered that chapter. For readability, one is referred to Figure 20.

To conclude the chapter, the lessons learned by applying the framework will be incorporated in the initial framework in order to enhance the framework. The enhanced framework is given in Section 11.2.

In the process of the case study, there will be several points of assumption, where the actual case of Mauritian may not be represented correctly. The field trip however, has delivered an understanding of the context considered in this report and many assumptions will be based on the first-hand experiences of the author and co-workers on site.

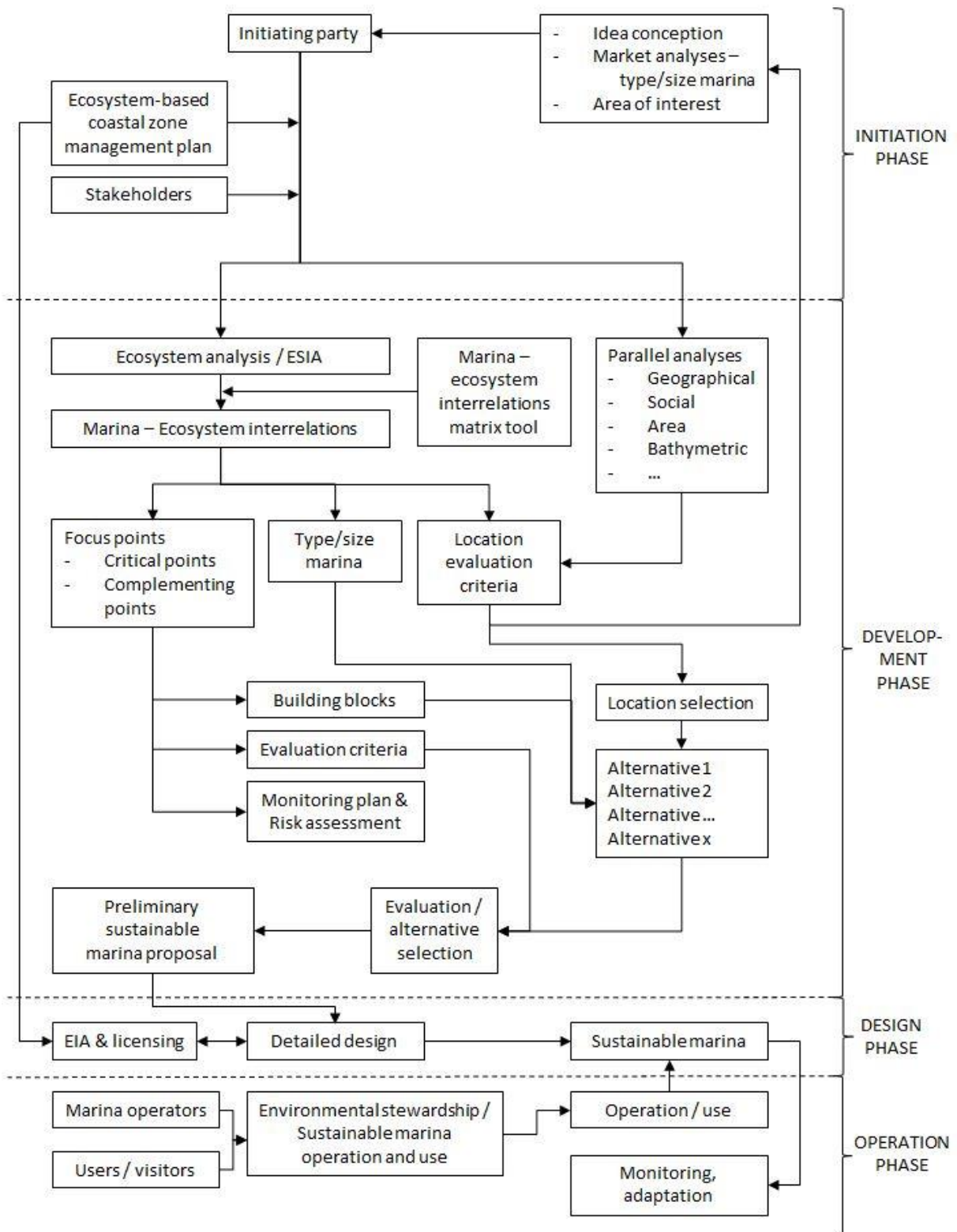
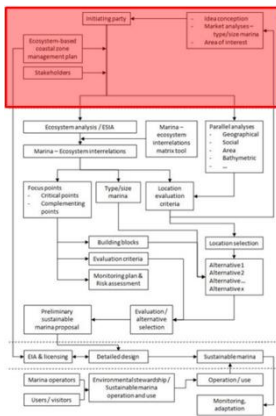


Figure 20 - Initial framework sustainable marina development

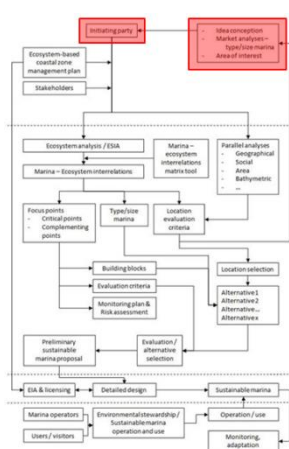
10.1 Initial framework – Initiation phase



As to be seen from Figure 20 and the framework viewer on the left, in the initial framework, several boxes can be seen in the initiation phase. Top box is the ‘initiating party’. As explained in Part I, this party can represent any party with the ambition to develop a marina of any type/size they see fit in any area. For the sake of this report, this party has been simulated to be as follows, resembling an actual organization in Mauritius.

Important to emphasize at this point, is that the initiation phase represents the starting point for the framework. It comprehends the very basics of the concept of a marina development. The initiator will have his own reasoning for a marina, based on some research or not, but this information may be altered by findings throughout further studies and the executing of the framework. Basics of the idea concept will be an area of interest, like a certain country or region, a certain marina purpose like for example recreation, real estate or super yachts and a basic idea of size. There may also be some goals the initiator wants to reach, like return on investment for an investor, or added value to the region for a city council.

10.1.1 Initiating party and basic marina concept

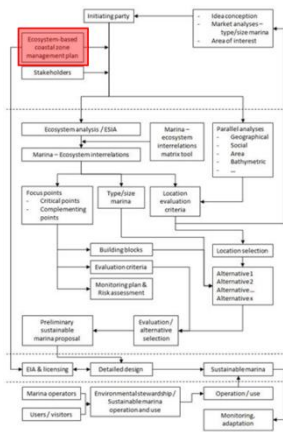


The initiator has the ambition to develop a commercial marina with a strong sustainable character, in the South West area of the island. The goal would be to have boats available for rental use, as well as berthing space for visiting yachts that have sailed around the island, or across the Indian Ocean. Sailing yachts, as well as motor boats would be welcome. Room for commercial tourist-oriented boats, like scuba diving-, whale-watching and cruising boats will be reserved. The initiator would like this marina to be inviting to the land-based tourists by adding (access to) recreational value to the area. This, in turn, is also meant to create jobs for local communities

and to provide a public place where local communities can meet, enjoy and make use of the present facilities and services. The marina will focus on eco-tourism, creating awareness for the Mauritian nature and sustainable development.

Although the initiator will offer haul-out services and storage area, large maintenance and boat building activities will be referred to existing facilities in Port Louis. From any location in the South West area, Port Louis would be very well reachable. Other destinations include the Grand Baie in the North, the Le Morne heritage sites in the South and the popular Île aux Bénitiers in the large lagoon. The marine area also offers some spectacular hotspots for whale- and dolphin watching.

10.1.2 Ecosystem-based coastal zone management plan



An assumption made for the sake of the case study is that an ecosystem-based coastal zone management plan is in place for all eco-regions in Mauritius. Truth is, this is not the case, as instead, an ICZM Framework is being implemented for the Mauritian coastal zone. Although similar in many aspects, the focus on the ecosystem as a whole and holistic view of the ecosystem-based management plan is preferred and deemed more appropriate for the sustainable management of the coastal zone. For the comparison and analysis of the ICZM Framework and EBM, one is referred to Part II of this report.

In Part I, the focus points of the EBM plan have been listed. To recap, these include stakeholder involvement, sustainable development, adopting an Ecosystem Services perspective, managing cumulative impacts, multiple objectives and the embracing of change, learning and adapting.

The EBM plan keeps an elaborate record of the ecosystem(s) around Mauritius. It aims at managing social, economic and environmental considerations in a sustainable way, to allow sustainable development in the coastal zone, without limiting its natural resources. Coastal developments are being monitored closely, mapping their impact and relation with its environment. By monitoring, research and education, a deeper understanding of the ecosystem functioning will be acquired.

To introduce a marina development in the area, the EBM plan will have to support the idea and implementation thereof. If the EBM plan does not approve of marina development in light of for example the cumulative impacts, or long-term objectives for the area, the marina development concept will be unfeasible.

For the area of interest, the South West, as indicated by the initiating party, the EBM plan translates this to the eco-region at hand. As from the section on Mauritius environmental information, Section 8.2, the eco-region considered for the South West area will be the Black River/ Le Morne region.

The Black River / Le Morne region has been characterized by a very active environmental zone. The lagoon, the Le Morne peninsula, the Île aux Bénitiers, the river outlets of the Rivière Noire and the Tamarin Bay are its main geographical features. The lagoon is protected by a coral reef and houses large fields of seagrasses and some patch reefs. A major part of the region has been marked as an environmentally sensitive area, specified by Landell Mills (2010). The area takes up most of the South West area of interest. At the northern end, the channel and Black River estuary limits the given sensitive area. Further north, in the Black River estuary, the Rivière Noire Fishing Reserve has been designated. It is forbidden to perform fishing activities in the area, as it is recognized and maintained as a nursery ground for fish species.

Figure 21 gives an overview of the South West eco-region, with specific features given. Roughly, the environmental aspects are shown and a zoning plan from the EBM plan is depicted. Also, onshore developments and activities, if present, are given.

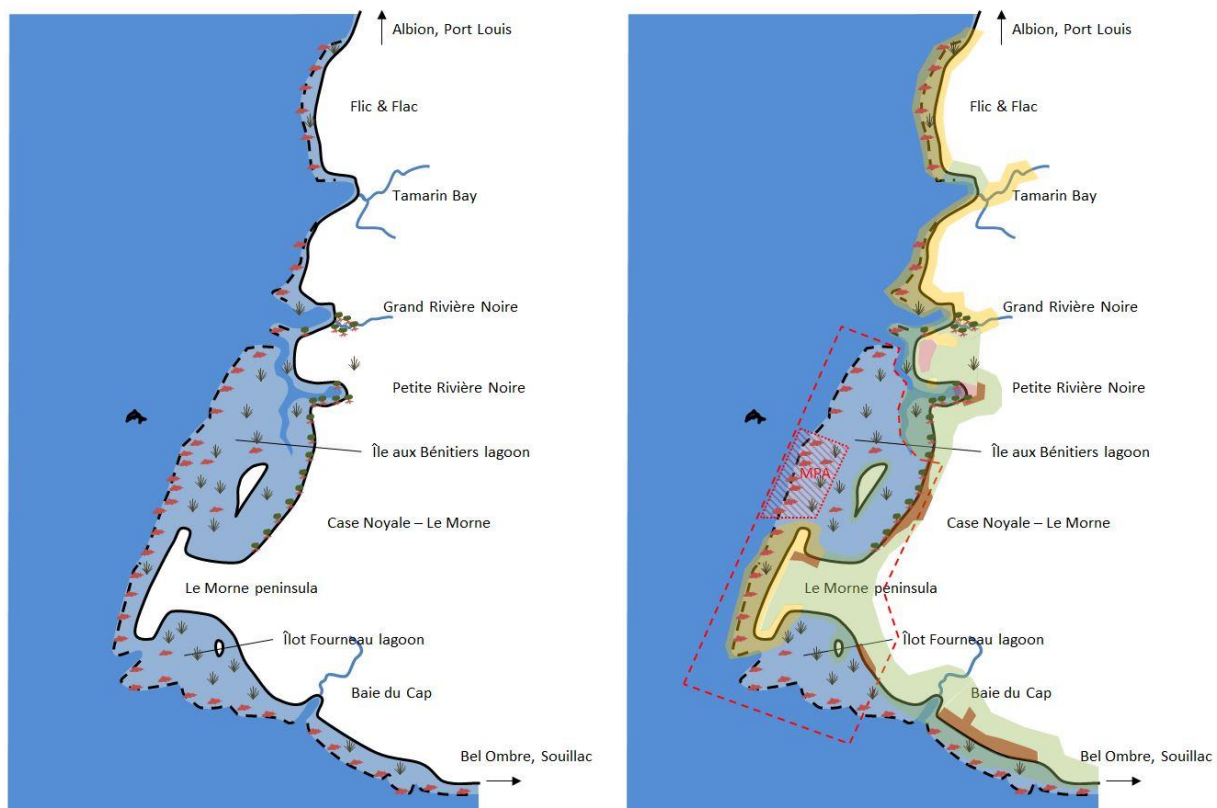


Figure 21 - South West eco-region, adopted from Landell Mills (2010)

Long-term, the country's outlook for the area is focussed on tourism/recreation and conservation. Also, the national aim has been expressed to declare the Le Morne peninsula as a UNESCO world heritage site. The iconic mountain Le Morne Brabant, its historic value regarding slavery and the natural beauty of the environment are qualifying reasons. By UNESCO, the conditions are given in response, entailing an improvement of environmental quality in the buffer zone, largely coinciding with the coastal zone.

As tourism, recreation and conservation are named as long-term goals for the area, commercial fishing is not supported in the area. It allows for artisanal fishery, but only in certain areas, enforced by the zoning plan and local coast guard.

To reach the long-term goals of the area, specific target objectives have been reported. The EBM plan recognizes the ecosystem and draws connections between interdependent elements of the ecosystem like the coral reef, sea grasses and the mangroves. Realising the importance of these links for biodiversity, ecological integrity and ecological resilience reasons, any development potentially

interfering with these relations, needs careful impact assessment. Like new developments, existing buildings, facilities and activities are subjected to environmental assessments as well. The cumulative impacts are being monitored and assessed at regular basis.

Tourism and recreation in the area is supported, but obliged to do so in co-existing with the natural environment. Eco-tourism is therefore encouraged. The EBM plan also foresees in designated bathing areas and zones that can be used for water skiing, and speeding.

Besides the environmental side of the EBM plan, the EBM plan aims to develop the region in socio-economical terms. It acknowledges local communities and requires local stakeholders to be involved in any proposed development, in development phases (local knowledge, concerns, wishes) as well as operation phases (local jobs, facilities, community area).

The EBM plan focal points and development requirements are listed as follows in Table 8.

Table 8 - EBM focal points and development requirements

EBM focal points and development requirements	
Long-term vision for South West eco-region	
▪ (Eco-) tourism / Recreation	
▪ Conservation	
Ecosystem-based coastal zone management	
▪ Marine zoning plan	Adherence required for sustainable development
▪ Information provision	Sub-regions, ecosystem intelligence
▪ Ecosystem assessment	Requirement for development proposals
▪ Socio-economic development	Local stakeholders, local communities
Government	
▪ Ministry of Environment	Licensing on coastal development
▪ Ministry of Housing and Lands	Licensing on land use / area development
▪ Ministry of Tourism	Licensing on marina operations

To bridge the gap from the EBM coastal zone plan to a marina development, the EBM focal points can be matched with the marina development's objectives. The focal points present a vision to development in the area, and in order to fit in with the area, this vision needs to be shared by the marina development.

The vision of the EBM plan is being operationalized by development requirements and zoning of the marine area. It provides boundary conditions for certain areas in the region as well as handholds on important ecological aspects in the area. Also, the EBM plan provides goals with a socio-economic context, like community development and local community integration.

Any preliminary marina proposal will have to align with the coastal zone management plan to succeed in further assessment (the EIA and other development licences).

At this step in the framework for sustainable marina development, several aspects are derived from the EBM plan at this point. Firstly, the eco-region that the area of interest is translated to, is obtained. With the eco-region, ecological aspects of the region are identified and several 'sub-regions' can be derived. These sub-regions are regions with similar environmental aspects (Ecosystem Services). To evaluate the various areas in the region for marina development, these sub-regions are adopted in the ecosystem assessment (Figure 22 and Table 9). The eco-regions have been determined in paragraph 8.2.4.

For the South West region, two distinct sub-regions can be identified, together with one other sub-region that knows three types of environments.

Table 9 gives the environmental aspects per area in the eco-region, and the subsequent division of sub-regions. Subdivision is based on main environmental aspects, which are derived from the EBM plan, together with important parameters like presence of a river discharge and bathymetry.

Three sub-regions are identified in the table, being 'coral beaches', 'mangroves' and 'river mouth'. These sub-regions, with their specific set of Ecosystem Services, will be used as input for the ecosystem assessment. The sub-region 'mangroves' has three different types, and will therefore be treated independently, but is likely to show large similarities in the ecosystem – marina relation assessment. Figure 22 and Figure 23 show the locations of the different sub-regions.

Table 9 - Environmental aspects per area

Area (North to South) \ Environmental aspects:	MPA / ESA	Coral reef <1 km	Mangrove	Seagrass	Bathymetry	River mouth	(Surge) exposure
Flic & Flac	.	X	.	./ X	Shallow	.	X
Tamarin Bay	.	.	.	.	Deep	X	X
Grand Rivière Noire	.	.	X	X	Deep	X	.
Petite Rivière Noire	.	.	X	X	Deep	.	.
Case Noyale – Le Morne	X	.	X	X	Shallow	.	.
Île aux Bénitiers lagoon	X	X	.	X	Shallow	.	./ X
Le Morne peninsula	X	X	.	X	Shallow	.	X
Îlot Fourneau lagoon	X	X	.	X	Shallow	.	X
Baie du Cap	.	.	.	.	Deep	X	X
Subdivision of eco-region:							
	'Coral beaches'; corals, shallow, exposed, pressure zone						
	'Mangrove'; mangroves				Deep, river mouth		
					Deep, no river mouth		
					Shallow, no river mouth		
	'River mouth'; river discharge, deep, exposed						

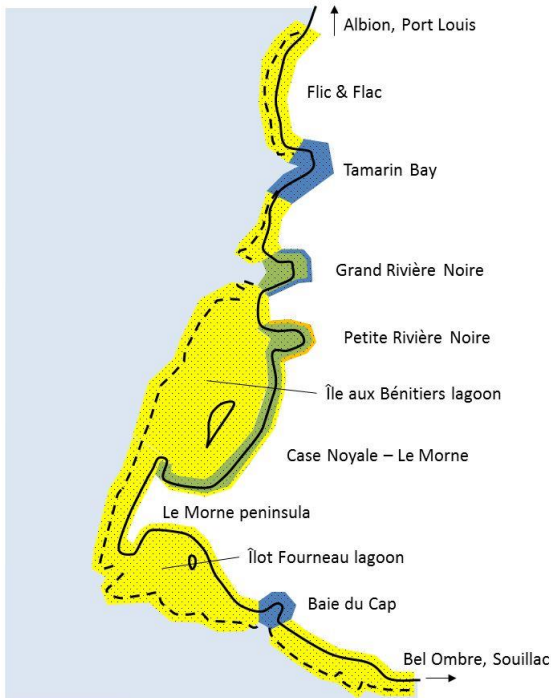


Figure 22 - Sub-regions South West eco-region

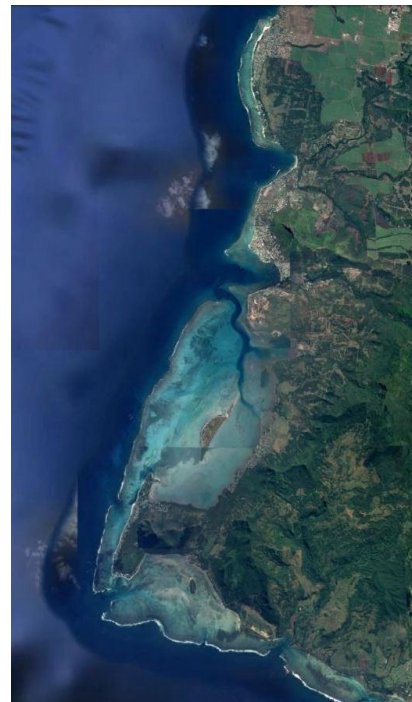
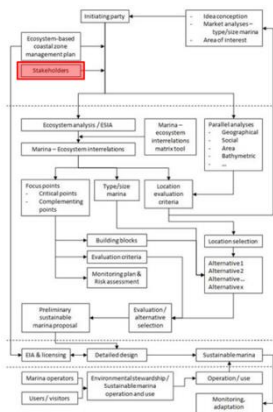


Figure 23 - Google Earth image South West eco-region

10.1.3 Stakeholders



Focal point of the ecosystem-based management in the coastal zone is stakeholder involvement (refer to Part I). Integration of functional requirements, societal choice, socio-economic factors and ecological values is key for a successful EBM strategy and a sustainable coastal zone. To be able to do this, it is critical to involve stakeholders representing these values during the initiation phase and throughout the development cycle. Benefits for the project include more information, increased trust, increased support and ultimately, an integrated (marina) development.

Stakeholder groups for the South West eco-region are grouped as follows (see Table 10), with respect to a sustainable marina development. For report purposes, the source of given stakeholder interests and values, is given in the far right column. A large share of the stakeholder information is obtained from the study performed for the ICZM Framework (Landell Mills, 2010). Especially local and regional interests are elaborated on. Also, their respective interest and power towards the project is given in an interest-power diagram, Figure 24.

Table 10 - Stakeholder groups with respect to marina development in the South West eco-region

Stakeholder group:	#:	Stakeholder:	Source:
Users;	1a	Tourists & marina users	Field trip Mauritius, interviews
	1b	Commercial	Assumption, Field trip
Community;	2a	Local fishermen, inhabitants	Assumption, focus group meetings
	2b	Regional council	Focus group meetings
	2c	Regional environmental health groups	Focus group meetings
Government;	3a	M/o Tourism	Public policy documents
	3b	M/o Environment & S.D.	Public policy documents
	3c	M/o Housing & Lands	Assumption, Field trip
	3d	Other governmental parties, national policy	Public policy documents
Marina;	4a	Developers	Assumption
	4b	Operators	Assumption, professional experience
Regional;	5	Competing developments & marine uses	Assumption, professional experience
NGO;	6	Conservation parties	Web-public information

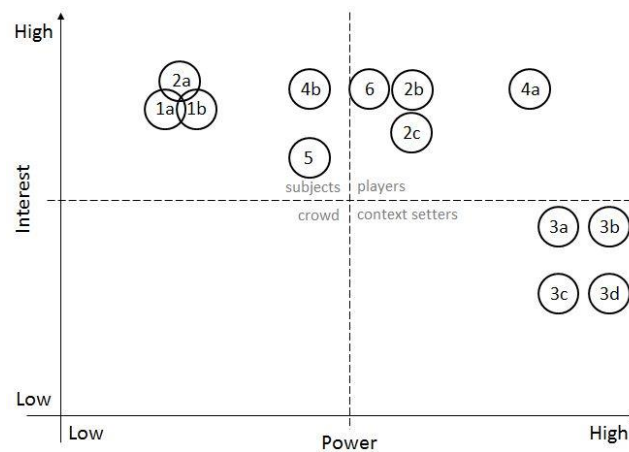


Figure 24 - Stakeholder diagram, numbers from table above

Below, all stakeholder groups and parties are briefly elaborated.

1a. Users – Tourists and marina users; This stakeholder group holds high interest in a potential marina development, as it offers non-existent facilities in the area. It provides shelter from cyclones, a perfect platform to undertake a range of tourist activities from and decent facilities for round-the-world or round-the-island sailors, looking for supplies, storage or merely an embarking point. From interviews among round-the-world sailors that were around at the time of field trip, such facilities are wished for and would be paid for. The potential customer potential is one of the driving reasons for the marina development in the first place. The group however, does not hold any direct power.

1b. Users – Commercial; This group represents those parties that exploit the by the marina attracted tourists and visitors. Restaurants, shops, boat rentals, sailing trips etc. are all dependent on the number of visitors attracted to the area and the marine facilities present. A marina would contribute to both and the group therefore holds large interest. Although a little more power over marina development plans in comparison to the tourist group, this group holds little power.

2a. Community – Local fishermen and inhabitants; A marina development in their community would have a large impact on the local community's lives. A marina would attract tourism and generate jobs for local people during construction phases as well as operation phases. The fact has been pointed out during a focus group meeting held in the communities of La Gaulette and Le Morne, that often new developments employ people other than the local inhabitants. For a new development to be supported locally, local work force should be employed. Another impact a marina may have on a community is the development of the communal area of the community with added services like ATMs, proper sewage systems, retail areas and markets. This is badly needed, according to the focus group meeting report (Landell Mills, 2010). Local fishermen also hold a specific interest; a marina would provide a safe and easy mooring space for their boats. It also may provide a specific area for the fishermen to display their goods and sell their catches. The marina should not, however, be too expensive to use and their current means of mooring and fishing areas need to be preserved.

2b. Community – Regional council; In the preparation of the ICZM Framework report, meetings have been held with the regional council, present in the environmentally sensitive area, which covers most of the eco-region considered for the marina development. They hold large interest for similar reasons as community level, and hold reasonable power over regional policy as well. The regional council is concerned with the socio-economic development and environmental health at their spatial scale. Some current regional problems have come up during the meetings;

- Little integration of local communities in area development projects (construction, operation), leading to little employment and poor communities,
- Villages in the region are generally underdeveloped, noting a lack of general facilities and opportunities for local youth,
- An environmental problem that has arisen is water quality around the entire pressure zone, deteriorating by domestic sewage and run-off. Improving the local sewage systems, by general area development, is important to the regional council,
- The regional council has started a program to promote environmental awareness among children in the region.

2c. Community – Regional environmental health groups; Community-based, several initiatives have risen that aim to conserve marine ecology in the coastal zone. Especially the lagoon around Île aux Bénitiers receives a lot of attention. The groups act by environmental education, control of marine activities and a voluntary coast guard service. The group is not benefitted by a marina development, and may have concerns of environmental origin. Their interest in the development may be less than the regional council's interest, but they do have some power to exert on a regional level, by either supporting the marina and its activities or disapproving and counteracting the development process. Involvement and empowerment may be good solutions in this case, by inviting them to educate on marina premises, raise environmental awareness and enforce zoning in the lagoon in the operation phase. During development, the groups may have important insights on current status of ecology, biodiversity and zoning in practice.



Figure 25 - Artisanal fishery Mauritius (source: Africa Money)



Figure 26 - Le Morne Brabant (source: Google Images)

3a. Government – Ministry of Tourism; A marina represents a spectrum of tourism that Mauritius has not yet experienced. It therefore offers an interesting market for tourism development, that aligns with the Ministry's policy of increasing numbers of visiting tourists. Marina development has only recently been adopted in Mauritian policy and supported across governmental institutions. For cultural reasons, marina development has not been on the Mauritian radar, resulting in the lack of marinas on the island. An important side note on tourism development, especially in the coastal zone, is that this should happen in a sustainable manner. Thus, the Ministry of Tourism has a large interest in marina development for tourism development reasons, and requires a sustainability mindset and adherence to coastal zone policy for any development. The sustainable marina concept, developed by the framework for sustainable marina development, aligns well with the Ministry's vision. Governmental parties exert power through binding regulations (law and licensing) and the government's ability to support the project financially. Their interest is on a national level, with less interest for the specifics of location or design, as long as adherence to sustainability guidelines is guaranteed.

3b. Government – Ministry of Environment and Sustainable Development; This Ministry's field of interest is very much aligned with the framework's goal; sustainable development. The framework's focus on the environmental aspects in the development process, the integration of national guidance of coastal zone management may be assumed to be supported by the Ministry. As coastal developments in the past have had and still have a large impact on the natural environment of the island and coastal development is not yet sustainable, the Ministry will follow the development proposal closely and has decisive power over the granting of licenses to proceed onto realisation.

3c. Government – Ministry of Housing and Lands; Although no specifics on marina development are given in public documentation on policy, the Ministry does manage land use in the coastal zone and is concerned with the development of coastal villages and communities. On socio-economical- and spatial area grounds, the ministry therefore has an interest in a marina development. The power to grant licenses gives this ministry decisive power over any marina development as well.

3d. Government – Other governmental organizations and national policy; Mauritian governmental parties like the Mauritian Tourism Authority and the Board of Investment also have an interest in marina development. These parties generally do follow – and execute – national policy though, and are likely to rank among the respective Ministries and national policy guidance. This means an urge to sustainable growth, respecting the natural environment's limits and societal choice. These parties do not often have any decisive power, but does influence the potential success by their support. The Board of Investment for example, could provide the framework for (foreign) investments, and the Mauritius Tourism Authority could incorporate the oncoming marina in their strategic marketing.

4a. Marina – Developers; This group represents the initiator or initiating organization, together with any investors, creditors and other internal stakeholders. Their goal in this case study, is to achieve a commercially viable marina based on eco-tourism and sailing activity. Important to this group will be achieving a return on investment within a reasonable timeframe. To realise the project, the development and design phase needs to address national policy, among which an ecosystem-based coastal zone management plan that needs to be adhered to. The latter is of mutual benefit; for sustainable marina viability, a sustainable coastal ecosystem is needed, and a coastal ecosystem can be aided by the presence of a marina and responsible marine activities through monitored activities and indirect area development.

This stakeholder group does present a condition based on their prospected customer base and experience from marina developments around the globe; the (artisanal) fishery should be kept clear from the general public area, docks and tourist areas. This condition rises from the disturbance, smell and associated effects the fishery business and fishermen may have on a marina. At best, marina developers may allow their boats to find shelter during heavy weather and a small marketplace for fishermen to sell their goods on marina premises.

4b. Marina – Operators; Every marina will need to be operated by a manager, harbour master, dock master, employees, charter companies, tour operators or a selection thereof. As for a sustainable marina environmental stewardship is required in its operation phase, personnel needs to be knowledgeable on the subject of marine impact and applying best practices to operate the marina in an environmental friendly manner. Part of their task will be to follow internationally accepted guidelines on marina operations. The Golden Anchor, Blue Flag or Clean Marinas scheme (refer to Part 0) could provide guidance and accreditation of environment-friendly statuses.

5. Regional – Competitive developments and marine uses; On existing developments, there are a large number of hotels and resorts in the region. Mainly around the Le Morne peninsula and near Tamarin, these areas attract a lot of tourists. A set of hotels and resorts have small private docks or moorings in front of their property to offer tour services to their guests. Some of these activities may be affected when similar activities are offered from the marina. On the other hand, the additional tourists attracted may stay at their accommodations. Another existing development is the La Balise marina. The marina offers berthing area and docks to be used by the real estate users. There is very limited space for visiting yachts. However, tourists that are looking to go sailing or general boating, may have an alternative now by mooring at the marina and staying elsewhere.

Foreseen developments are additional hotels and/or resorts along the coast, although the more scenic areas have been fully developed already. Another foreseen development is the creation of an eco-resort on the île aux Bénitiers. The eco-resort aims to offer similar access to the beautiful marine

area as the marina aims to do. The eco-resort does not include berthing area, but may provide mooring buoys in the lagoon. The resort is being criticized and its licensing is unsure at the moment.

For existing developments as well as for the foreseen developments, a plan for co-existence could be implemented. The regional, conflicting developments may want to use the marina facilities for shelter and ease of use. Also, tourists attracted by either the hotel/resort or the marina may be 'shared' between them, stimulating both businesses.

6. Non-governmental parties; From different spatial scales parties concern themselves with, for example, the well-being of the Mauritian coastal waters. Mauritian-based parties are the Reef Conservation Mauritius, Mauritian Marine Conservation Society and the Lagon Bleu organization. All three strive for education around and conservation of marine ecology in Mauritius. On an Indian Ocean scale, also several NGOs are actively concerned with the Mascarene Islands, including Mauritius. Examples are the Indian Ocean Commission and the Agulhas and Somali Current Large Marine Ecosystems (ASCLME) Project. These organizations often look at a larger scale, rather than the very location-specific activities of the Mauritian-based parties. On a global scale, international parties are the WWF, UNDP and GEF. These organizations often support the smaller scale organizations by supplying funds, expertise and/or equipment.

Concluding the stakeholder listing, the expressed interests need to be incorporated in the development process. Based on the knowledge of interests and understanding of relative power, a plan to engage the stakeholders during the development process needs to be set-up at this point. Roughly, five types of stakeholder approaches can be distinguished; inform, consult, involve, collaborate or empower (Bryson, 2004).

Broadly, although all groups have a large interest in a marina development, little direct opposition for a like development arose. Conditions apply though, on both an environmental and a socio-economic aspect. Environmentally, the conditions are about the impact the marina and the marina operation may have on the ecosystem. From a governmental perspective, the project will have to align with the coastal zone policy in place. From a more local perspective, the marina should not have direct negative impacts in terms of habitat destruction or ecosystem degradation. Socio-economically, the marina is welcomed, on a national as well as a regional and local level. The attracted tourism, the development of the region and the opportunities it offers for local communities in terms of jobs and welfare are welcomed across the stakeholder board. Sustainable development is key though, and a strong focus on the environmental aspects of the development will be necessary throughout the development process. As the marina aims for an eco-tourism market and is largely benefitting from a sustainable approach to development, most interests are shared by the stakeholders.

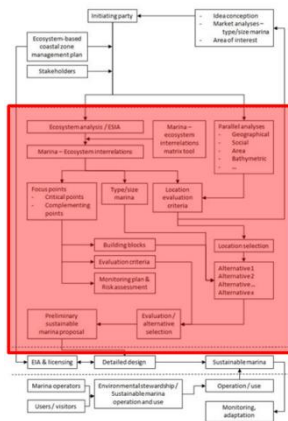
Little conflicting interest may rise from developments and marine uses in the region, but there are plenty reasons where a co-existence plan could be implemented, benefitting both.

Table 11 - Stakeholder involvement approaches

Stakeholder group:	#:	Stakeholder:	Approach:	Remark:
Users;	1a	Tourists & marina users	Inform	No direct power, but aiming for 'eco-tourism'.
	1b	Commercial	Consult	Their preferences and needs are taken into account.
Community;	2a	Local fishermen, inhabitants	Involve	Their support for the project is of large importance. Local knowledge.
	2b	Regional council	Collaborate	Their advice will be incorporated.
	2c	Regional environmental health groups	Collaborate	Their advice will be incorporated.
Government;	3a	M/o Tourism	Collaborate	Their legislation and vision will be shared by the marina.
	3b	M/o Environment & S.D.	Collaborate	Their legislation and vision will be shared by the marina.
	3c	M/o Housing & Lands	Involve	Less power than other ministries, but a needed partner.
	3d	Other governmental parties, national policy	Consult	Advice and recommendations from the various parties will be taken into account.
Marina;	4a	Developer	Empower	This is the driving force.
	4b	Operators	Collaborate	Their view on marina operations is valued, together with guidelines on sustainable marina operations.
Regional;	5	Competing developments & marine uses	Consult	Search for co-existence plan, shared interests.
NGO;	6	Conservation parties	Empower	These parties have great knowledge and a history of education on ecosystems. Their contribution will help the sustainable character of the development.

The approaches per stakeholder are incorporated in the initial framework at several steps of the process. In the initiation phase, all stakeholders are involved, providing multi-sectoral- and local knowledge. Along the framework, more closely involved stakeholders have a part in the marina development process by either consultation, collaboration or involvement. Ultimately, some parties are empowered and take on a certain responsibility in subsequent design and operations stages.

10.2 Initial framework – Development phase



With an outline of the initiator's initial ideas for a marina, input from the ecosystem-based coastal zone management plan and an approach strategy for stakeholder involvement, the initiating phase has been concluded. Input for the next phase has been derived: the sub-regions, an overview of existing ecosystems, stakeholder interests and political views/policy among others. This information is taken forward in the development phase, where the initial idea for a marina will be taken to a preliminary marina proposal after several analyses, location selection, alternative creation and evaluation cycles.

The first stage of the development phase involves carrying out analyses on all relevant aspects (Paragraph 10.2.1). There are area analyses, geographic analyses, market analyses, social analyses, bathymetric and hydrodynamic analyses, and explicitly included in this framework, the ecosystem analysis. The latter will be focussed on in this report, with the ecosystem – marina matrix tool. Other analyses will be treated, but less elaborately considered in the report.

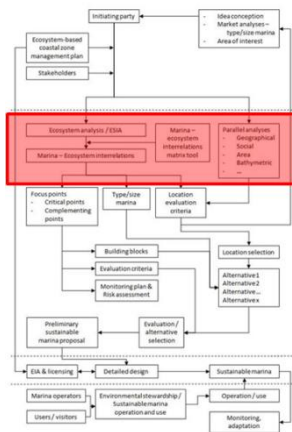
Secondly, after analyses, a location selection takes place. From various analyses, location selection criteria may come forward that guide the selection process. In this framework, the ecosystem analysis gives important input information as well. Environmental considerations will have a great impact on where, and also if, a marina development can take place.

For a given location, the analyses will have provided information. Considering the environmental analyses, obtained information will be on the present Ecosystem Services, and focal points for any marina development in that location. Some ecosystem elements may be pressured by a marina development, whereas other elements may contribute to a marina. Also, some elements may be aided by a marina development.

With a location in mind and information regarding the location obtained, alternatives may be developed, which then can be evaluated compared to each other, and a no-development option. Evaluation criteria treat the marina holistically, on all aspects that affect the sustainable character of the development, on ecological, social, economic and political grounds.

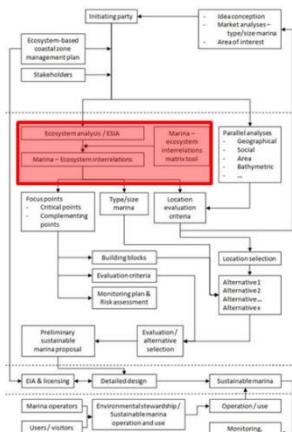
After evaluation, a preliminary proposal will be drawn up. It will present a rough marina proposal, without extensive detailing, but giving the general idea and important elements of the proposed marina development.

10.2.1 Development phase – Analyses



As introduced, the ecosystem analysis is focussed upon in the framework, as well as in the report. Other analyses are considered briefly. For a proper marina development study this would be insufficient, as aspects of importance may be left out. The shortcoming is acknowledged and taken up in the recommendations section at the end of the report.

Ecosystem analysis



The analysis starts with the given sub-regions from the ecosystem-based coastal zone management plan. The management plan provides information on present ecology and ecosystem status. Based on similar sets of ecosystem features of different areas in the eco-region, the sub-regions have been derived. Refer to Table 9 and accompanying figures for an overview of the area and region division.

Three sub-regions have been identified; the ‘coral beaches’ regions, which feature coral reefs, shallow lagoons with seagrasses, carbonate sand beaches and in this eco-region, has been marked as an environmentally sensitive area. The ‘river mouth’ regions are characterized by the presence of river discharges, which has naturally led to a non-presence of corals in their direct vicinity. The regions also have natural access to deep water (channels), with bare sea bottoms with occasional sea grasses. Exposure to waves and currents is present. Sediment in these areas is also of a different kind, with muddy and silty depositions around the river mouth and coastal banks. Ecologically, less biodiversity and ecological sensitivities are found in these regions. The ‘mangroves’ regions knows three sub-sets, as the mangroves can either have nearby river discharge, different water depths, ranging from deep to shallow waters, or a combination. These features have large effects on what effect any marine development would have and therefore are considered separately. In general, ‘mangrove’ regions are coastal areas with large mangrove presence, presenting a large ecosystem value. Sediments can be mixed carbonate and river sediments, depending on its respective location.

The sub-regions provide different Ecosystem Services, or better, provide the same Ecosystem Services in a different degree, compared to each other. The degree of ecosystem service provision is

supplied by the EBM plan and is listed as follows for the different sub-regions (Figure 27). In the same figure, a general indication of the interest a marina has with the different Ecosystem Services.

In Figure 28, per sub-region the degree of marina elements is given. Because of their distinct features, different marina elements will be more important or present in a design than others. Solid structural elements like breakwaters or a pier will be more pronounced in deep or exposed waters, whereas a shallow and sheltered sub-region may not even include such elements.

Refer to Appendix A. Marina elements and Appendix B. Marine and coastal Ecosystem Services **Error! Reference source not found.** for elaboration of marina elements and marine and coastal Ecosystem Services, respectively.

		#	1	2	3	4	5	6	7	8	9	10	11	12	13	
Ecosystem service:	Provisioning			Regulating and maintenance									Cultural			
	Food provision	Water storage and provision	Biotic materials and biofuels	Water purification	Air quality regulation	Coastal protection	Climate regulation	Ocean nourishment	Life cycle maintenance	Biological regulation	Symbolic and aesthetic values	Recreation & (eco-)tourism	Cognitive effects			
Eco-region / Sub-region:																
South West	'Coral beaches':	5	0	4	3	2	5	2	3	5	2	5	5	5		
	'River mouth':	1	0	1	1	1	3	3	2	1	1	1	1	1		
	'Mangroves':	2	0	5	3	4	5	5	4	5	2	4	3	3		
Interesting for marina:		0	0	3	5	3	5	1	1	5	2	5	5	3		

Figure 27 - Degree of Ecosystem Services provision per sub-region and degree of marina interest in ES

Example to clarify Figure 27: For the 'coral beaches' sub-region, coastal protection is given the rating '5', which is the highest score. This is done because of the qualities the Mauritian reef has in the attenuation of waves and the influence they have on the morphodynamics in the area. Also, the reef indirectly supports beach accretion by accommodating bivalve organisms and algae, and beach accretion is also beneficial to coastal protection.

Eco-region / Sub-region:			South West		
			'Coral beaches'	'River mouth'	'Mangroves'
#	Marina element:				
1	Marina	Structural elements	3	5	5
2		Floating elements	3	3	3
3		(Maintenance) dredging	5	2	5
4		Bottom structures	3	3	3
5		Construction & maintenance	5	5	5
6	Marina use	Boat presence	3	3	3
7		Onshore activities	3	3	3
8		Social- / Community places	3	3	3
9		Marine activities	3	3	3

Figure 28 - Degree of marina elements present per sub-region

In Part I of the report, the initial framework included a tool to determine marina – ecosystem interaction. This is done by pitting the Ecosystem Services (a representation of the marine ecosystem) against the marina elements that affect its environment. Marina elements include the construction and use of these elements and marina activities during operation. The interrelation signifies the mutual impact and is rated from very negatively (--) to very positively (++). An interrelation that has both positive and negative effects is given an (+/-) and no relation is shown with a (0). All ratings are colour-coded.

Important to realize, is that these ratings are based on available knowledge and can be improved based on experience and knowledge building. An important aspect of ecosystem-based management, ‘to embrace change, learning and adapting’ (refer to Part 0), is being applied at this stage. Also, although interrelations are being rated, these ratings are evaluated qualitatively, meaning there is a line of thinking behind it, which may vary in different settings.

The next figures give the completed matrix tool for the three sub-regions with a marina development. To aid understanding of the tool, a few interrelations are elaborated below.

- 1) In the matrix for sub-region ‘coral beaches’, the marina element of structural elements is considered. It is evaluated for all Ecosystem Services, and as one can see, it scores varyingly across the different Ecosystem Services. First, the ES ‘food provision’ i.r.t. the structural

element is evaluated. The addition of a structural element will require space and stops that area from being utilized for artisanal fishing, which is currently being done in the sub-region. Solid elements will also change the morphodynamics in the area, which is likely to impact a wider area. Together, the interrelation is given a negative (-) score. Note that the marina element 'structural elements' is given a '3'- degree, indicating these elements will not be of a massive size (shallow waters, natural shelter present). This mitigates the negative effect.

- 2) For sub-region 'river mouth', different degrees of Ecosystem Services are present. There are no direct coral reefs present, deep waters and muddy sediments from the river discharge. The sub-region does not provide large Ecosystem Services, represented by small values at the horizontal, under the Ecosystem Services. The most important one here, is 'coastal protection', as the river discharge services the area by discharging the water, and supplies sediment to the area, adding to the coastal area's ability to withstand any erosion. Structural marina elements would have a large effect on this by changing water flows, sedimentation patterns and potentially, water discharge times. A very negative score (--) has been given.
- 3) To add bottom structures in the 'mangroves' regions, which are characterized by mangroves, but also seagrasses, a negative effect as well as a positive effect can be expected. Positive, by creating habitat area (ES: life cycle maintenance) and increased vegetation area (ES: water purification). These bottom structures are often used for anchoring of cables, mooring lines and mooring chains. The latter is known to have a negative effect on the sea bottom by sweeping and destroying vegetation and disrupting sea bottom life. A positive/negative (+/-) score was given.

On the next few pages, the filled out matrices have been depicted. After each matrix, the sub-region specific findings are evaluated. First, some general findings are given below.

It is true for all sub-regions that there is a general negative relation between a marina development and its environment. Marina elements 'structural elements', '(maintenance) dredging', 'construction & maintenance', 'boat presence', 'onshore activities' and 'marine activities' all score negative for most Ecosystem Services. Although most impacts are only little negative '-', the dredging element and the onshore activities element can have a very negative impact on the environment and should therefore be avoided or mitigated for any marina development.

Positive relations are received from floating structures, and social-/ community places. The latter can have a positive impact by education, monitoring of environmental statuses and supervision of marine activities.

One is advised to value the different scores in the matrix by the scores given per marina element and the score given to each ecosystem service that is present to a greater or lesser extent. These scores

are elaborated in Figure 27 and Figure 28. For example, in Table 12, the double minus score for 'dredging' vs. 'life cycle maintenance' is or larger importance than the same double minus for 'dredging' vs. 'air quality', because life cycle maintenance is a more pronounced ecosystem service.

Coral beaches

The marina – coral beach ecosystem matrix has been given in Table 12. The ‘coral beach’ ecosystem provides many Ecosystem Services, from all services groups. Noteworthy is the provision of cultural services. The set of Ecosystem Services do match exceptionally well with the set of services that is interesting to marinas (see Figure 27).

Table 12 - Marine - Coral beaches ecosystem relation matrix

#	'Coral beaches'												
	1	2	3	4	5	6	7	8	9	10	11	12	13
	Provisioning			Regulating and maintenance							Cultural		
	Food provision	Water storage and provision	Biotic materials and biofuels	Water purification	Air quality regulation	Coastal protection	Climate regulation	Ocean nourishment	Life cycle maintenance	Biological regulation	Symbolic and aesthetic values	Recreation & (eco-)tourism	Cognitive effects
	5	0	4	3	2	5	2	3	5	3	5	5	5

Ecosystem service:
(based on Liqueste *et al.*, 2013)

Marina element:

1	Marina	Structural elements (quay walls, breakwaters, fixed jetties)	3	-	0	0	--	-	+/-	0	-	+	0	-	+	0
2		Floating elements (floating breakwaters, pontoons)	3	-	0	0	0	0	+	0	0	+	0	-	+	0
3		(Maintenance) dredging (marina basin, navigation channel)	5	-	0	-	--	--	--	0	0	--	0	-	+	0
4		Bottom structures (jetty anchoring, navigation marks,	3	0	0	0	+/-	0	0	0	0	+	0	-	+	0
5		Construction & maintenance	5	-	0	0	-	-	0	-	-	--	-	--	-	-
6	Marina use	Boat presence (moored boats, engines, boat wastes)	3	-	0	0	-	-	0	-	-	-	-	-	+	0
7		Onshore activities (noise, stormwater run-off, nutrients)	3	--	0	-	--	-	-	-	--	--	--	--	-	-
8		Social- / Community places (education center, yacht club)	3	0	0	+	0	0	0	0	0	+	0	+	+	+
9		Marine activities (sailing, tour operating, speeding, fishing)	3	-	0	-	-	-	0	-	-	-	-	-	+/-	+/-

Ecosystem service: #

Eco-region / Sub-region:

South West	'Coral beaches':
	'River mouth':
	'Mangroves':

5	0	4	3	2	5	2	3	5	3	5	5	5
1	0	1	1	1	3	2	2	1	1	1	1	1
2	0	5	3	4	5	5	4	5	2	4	3	3

Interesting for marina:

0	0	3	5	3	5	1	1	5	2	5	5	3
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For the 'Coral beach' ecosystem, a marina development has many negative relations, compared to the other sub-regions of 'River mouth' and 'Mangroves'. This is mainly due to its delicate nature of coral reefs and seagrasses in combination with the shallow character of these areas. Because it is shallow, dredging works will be necessary for a marina development in this sub-region.

Also, as all coral beach areas are subject to severe wave attack during storm surges, there is a need for structural defences. This alters the morphodynamics in the area, which is an important parameter for coral ecosystems. Structural works do also have a positive relation in this type of region, as it creates additional habitat and tranquil conditions for all kinds of species of flora and/or fauna.

As the area features very delicate and sensitive elements, the risk of adding pollutants, nutrients and human presence to the area is high. Strict regulations about storm water run-off, boat pollutants, sewage and domestic wastes and other polluting materials would have to apply to mitigate the effects. For marine activities this is true too, and because the 'base' for the marine activities, the marina' is in the marine area of interest, these boats and boatmen must take their environmental stewardship to an accepted level. Guidelines for sustainable operation and boat use are readily available with initiatives as mentioned in Part 0 of the report.

Another potentially bad relation with the coral beach ecosystem may be construction and maintenance works. The presence of materials, equipment, construction activity and accompanying pollution to the water body, air and land area will affect the ecosystem's ability to provide numerous Ecosystem Services.

Marina elements that are likely to have a positive relation with the environment are floating structures, and to a lower extent, bottom structures. They score well with Ecosystem Services of 'life cycle maintenance' and 'recreation & eco-tourism'. Also, as stated in the general findings, 'social-/community places' will be beneficial to the environment as well.

River mouth

This sub-region type represents two areas in the South West region; Tamarin Bay and Baie du Cap. For the river mouth sub-regions, Ecosystem Services are relatively less pronounced, shown by the low scores in the Ecosystem Services values. For a marina in this environment, structural elements are required, and construction & maintenance may have a large impact. Dredging however, is unlikely to happen to large extent, and hence has been given a score '2'.

Table 13 - Marine - River mouth ecosystem relation matrix

#	'River mouth'												
	1	2	3	4	5	6	7	8	9	10	11	12	13
	Provisioning			Regulating and maintenance						Cultural			
	Food provision	Water storage and provision	Biotic materials and biofuels	Water purification	Air quality regulation	Coastal protection	Climate regulation	Ocean nourishment	Life cycle maintenance	Biological regulation	Symbolic and aesthetic values	Recreation & (eco-)tourism	Cognitive effects
	1	0	1	1	1	3	2	2	1	1	1	1	1

Ecosystem service:
(based on Liqueste *et al.*, 2013)

Marina element:

1	Marina	Structural elements (quay walls, breakwaters, fixed jetties)	5	+/-	0	0	--	0	--	0	-	+	0	-	+	0	
2		Floating elements (floating breakwaters, pontoons)	3	0	0	0	0	0	+/-	0	0	+	0	-	+	0	
3		(Maintenance) dredging (marina basin, navigation channel)	2	0	0	0	0	0	+	0	0	0	-	0	0	+	0
4		Bottom structures (jetty anchoring, navigation marks,	3	0	0	0	+/-	0	0	0	0	0	+/-	0	-	+	0
5		Construction & maintenance	5	0	0	0	-	-	-	0	-	-	-	-	-	-	-
6	Marina use	Boat presence (moored boats, engines, boat wastes)	3	-	0	0	-	-	0	0	-	-	-	-	+	0	
7		Onshore activities (noise, stormwater run-off, nutrients)	3	-	0	-	--	-	0	0	--	--	--	-	-	0	
8		Social- / Community places (education center, yacht club)	3	0	0	+	0	0	0	0	0	+	0	+	+	+	
9		Marine activities (sailing, tour operating, speeding, fishing)	3	-	0	0	-	-	0	-	0	0	0	-	+/-	+/-	

Ecosystem service: #

Provisioning			Regulating and maintenance						Cultural			
1	2	3	4	5	6	7	8	9	10	11	12	13

Eco-region / Sub-region:

South West	'Coral beaches':
	'River mouth':
	'Mangroves':

5	0	4	3	2	5	2	3	5	3	5	5	5
1	0	1	1	1	3	2	2	1	1	1	1	1
2	0	5	3	4	5	5	4	5	2	4	3	3

Interesting for marina:

0	0	3	5	3	5	1	1	5	2	5	5	3
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A marina development in the river mouth sub-regions, would have a neutral to little negative relation on most interrelations between its elements and surrounding Ecosystem Services. No mangroves are in the vicinity, and neither are the coral reefs. On the seabed, river sediment covers the direct area, resulting in little sea grass coverage in the channels.

A large difference to be seen, compared to the other two sub-region types, is the neutral scoring for (maintenance) dredging. This is because the river mouth areas feature large natural depths, less vegetation and feature no corals or mangroves in the direct area.

Negative relations are similar to the general findings for all ecosystems. Hard structural elements like breakwaters and piers will affect a number of Ecosystem Services negatively. Also, onshore activities may cause a negative relation with a large amount of Ecosystem Services. These should be limited by sustainable operations, and environmental stewardship on- and offshore.

At these locations, severe wave attack can be expected, due to orientation, bathymetry and absence of wave-attenuating elements like coral reefs, shallow lagoons or mangroves. By this information, the hard structural are likely to be included in the design in order to guarantee shelter within the harbour. Floating elements, although providing some beneficial elements to the ecosystem, are generally not operational in heavy wave climates and may fail. Especially for long waves, as they can be witnessed at Baie du Cap, floating structures are probably not an option. Modelling of wave climates and water levels could prove the point.

Mangroves

This sub-region is subdivided in three types. Mangrove (blue) for the Grand Rivière Noire area, Mangrove (orange) for the Petite Rivière Noire and Mangrove (yellow) for the coastal stretch of Case Noyale to Le Morne. As stated before, the largest differences are the presence or absence of a river discharge and the bathymetric environment, which is deep for the Rivière Noire areas, but very shallow for the Case Noyale – Le Morne stretch of coast.

Table 14 - Marine - Mangrove ecosystem relation matrix

#		'Mangroves'												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Ecosystem service: (based on Liqueste <i>et al.</i> , 2013)		Provisioning			Regulating and maintenance						Cultural			
		Food provision	Water storage and provision	Biotic materials and biofuels	Water purification	Air quality regulation	Coastal protection	Climate regulation	Ocean nourishment	Life cycle maintenance	Biological regulation	Symbolic and aesthetic values	Recreation & (eco-)tourism	Cognitive effects
		2	0	5	3	4	5	5	4	5	2	4	3	3

Marina element:

#	Marina element:	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Marina Structural elements (quay walls, breakwaters, fixed jetties)	5	0	0	--	-	--	-	-	+	0	-	+	0
3		1	0	0	0	0	+/-	-	0	+	0	-	+	0
2		3	0	0	0	0	+	-	0	+	0	-	+	0
3	Marina (Maintenance) dredging (marina basin, navigation channel)	5	0	0	--	--	--	--	0	--	0	-	+	0
2		2	0	0	--	--	--	--	0	--	0	-	+	0
5	5	0	0	-	--	--	--	--	0	--	0	-	+	0
4	Marina Bottom structures (jetty anchoring, navigation marks,	3	0	0	+/-	0	0	0	0	+/-	0	-	+	0
5	Construction & maintenance	5	0	-	-	-	-	-	0	-	0	-	-	-
6	Marina use Boat presence (moored boats, engines, boat wastes)	3	0	0	-	-	0	-	-	-	-	-	+	0
7		3	0	-	--	-	--	--	-	--	-	-	-	0
8		3	0	0	+	0	0	0	0	0	+	0	+	+
9	Marine activities (sailing, tour operating, speeding, fishing)	3	0	-	-	-	0	-	-	-	-	-	+/-	+/-

Ecosystem service: #

Eco-region / Sub-region:

South West	'Coral beaches':
	'River mouth':
	'Mangroves':

#		Provisioning			Regulating and maintenance						Cultural			
		1	2	3	4	5	6	7	8	9	10	11	12	13
		5	0	4	3	2	5	2	3	5	3	5	5	5
1		0	1	1	1	3	2	2	2	1	1	1	1	1
2		0	5	3	4	5	4	4	4	5	2	4	3	3

Interesting for marina:

0	0	3	5	3	5	1	1	5	2	5	5	3	3
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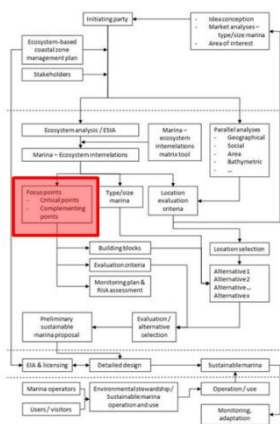
The mangrove areas provide many Ecosystem Services. Especially in terms of regulation and maintenance services, the mangroves and seagrasses create a functional ecosystem. Mangroves (and to a lesser extent, seagrasses) are sensitive to change in their environment. Conditions like calm waters, salinity levels and water quality are important for its survival. At the named 'mangroves' locations, some replanting programmes have successfully planted mangroves to re-introduce a prior downfall of mangroves in the area. The idea is to create mangrove area, so it will support the ecosystem by providing habitat area, ocean nourishment and water quality. It also provides a coastal protection function, by stabilizing the coastline and attenuation of waves and surges.

The marina elements change somewhat in priority considering the differences in mangrove areas. The deeper, the more structural works are needed, but the less any dredging is required. This has been reflected in Table 14 by the narrow rows for 'structural elements' and '(maintenance) dredging'.

A marina near mangroves needs to be careful to maintain the right conditions for mangrove health, and restoration. Dredging works too close to mangrove area, affecting their sediment supply, or wave action patterns, may result in fewer mangroves and subsequently, less Ecosystem Services to be obtained from the ecosystem. Dredging works can still take place if conditions for mangroves are still honoured.

Other potential negative impacts may arise from onshore activities, as accounts for all considered marine ecosystems. Social-/ community places can contribute to the ecosystem in a positive way by monitoring mangrove health, organizing conscientious tourism activities and education programmes. Also, by providing the means to closely monitor the mangroves and ecosystem development over time, a better understanding can be achieved of how these ecosystems work and how a marina relates to its environment.

Focal points



From the marina – ecosystem interrelation matrices, where Ecosystem Services represent the ecosystem and the marina elements represent the marina and marina use, several focal points can be identified for each sub-region. These focal points can be positive or negative interrelations, complementing features or opportunities for positive marina – ecosystem interaction. Table 15 below shows the focal points per sub-region, based on the evaluation given in the ecosystem analysis paragraph. These focal points will be the basis for design considerations, evaluation criteria and monitoring & risk assessment plans.

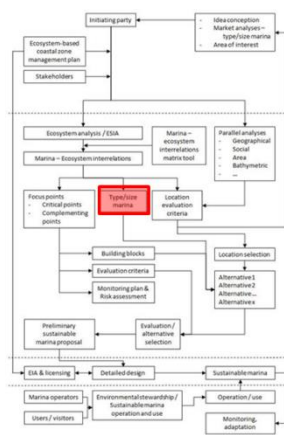
Table 15 - Focal points for each area, based on the marina - ecosystem relation matrices

Area (sub-region)	Focal points
<p>Flic & Flac (Coral beach)</p>	<p>The coral beach area houses critical, and vulnerable, habitat zones. Besides habitat, the area offers regulating and maintenance services as well as cultural services to a large degree.</p> <p>In this area, dredging activities will have a very negative effect on the ecosystem, as well as onshore activities and construction activities will. These ‘marina elements’ are strongly represented in this area though, as seen from Figure 28.</p> <p>Hard structural elements like breakwaters will have positive as well as negative effects, but an alternative, floating structures, may have beneficial effects on the ecosystem.</p> <p>The most affected Ecosystem Services by a marina in this area are ‘water purification’ and ‘life cycle maintenance’, together with ‘aesthetic values’, ‘air quality maintenance’ and ‘food provision’. In general, the ecosystem is negatively affected by a marina development, in this area. The loss of Ecosystem Services is explained by the vicinity of coral reef area, the need for dredging and the destruction of sea grass beds.</p>
<p>Tamarin Bay (River mouth)</p>	<p>The river mouth area of Tamarin shows less negative effects of a marina development on the local ecosystem. Because of the larger depth, less dredging is required and less destruction of sea bed, and sea grasses will take place. Also, no coral reefs or sensitive mangroves are present.</p> <p>As dredging may aid in the river discharging, any dredging in the channel, may actually have some beneficial effect to the ecosystem service of ‘flood protection’, by inducing better storm water discharge.</p> <p>Negative effects the marina does have are mainly due to onshore activities, construction and maintenance and boat presence. Hard structural elements that impact the river flow may limit the river’s ability</p>

	<p>to discharge and therefore have a negative impact on coastal protection. If it does not limit river discharge, however, the structural elements can be used to enhance coastal protection, and create additional habitat area, in more quiet water bodies in the process.</p>
<p>Grand Rivière Noire (Mangrove, river)</p>	<p>The Grand Rivière Noire area houses mangroves in the area, together with a river discharge (hence the name) and has direct access to deep water. Mangroves provide an important share of Ecosystem Services in the area and therefore should be preserved and even stimulated.</p> <p>The river discharges sediment to the area, leading to a need for maintenance dredging, which has a negative impact on several regulating and maintenance services and also the survivability of mangroves.</p>
<p>Petite Rivière Noire (Mangrove, deep)</p>	<p>Similar to Grand Rivière Noire, the area features mangroves and access to deep water. National initiatives to plant mangroves at this location have proven successful. A difference with the Petite Rivière Noire location is the absence of a river discharge, despite its name.</p> <p>Although there is no sediment being discharged from a river, siltation does occur, by slow moving water in the bay. The shallow shores make great conditions for mangroves.</p> <p>(Maintenance) dredging should be avoided at this location for aforementioned reasons concerning the mangroves. Also onshore activities and their pollutants form a potential threat to the ecosystem at this location.</p> <p>There are no coral reefs or shallow sea grass beds in this area, but there are in the direct vicinity, across the deep channel. The marina and its structures are not likely to impact the area across the channel, but its use (including boating etc.) would.</p>
<p>Case Noyale – Le Morne (Mangrove, shallow)</p>	<p>The third mangrove area naturally features mangroves. It is shallow and borders to the coral beach areas. It is a shallow area with large sea grass quantities. The shallow area supports the mangroves.</p> <p>For this area, from the matrix, it can be seen that dredging activities would drastically change the area's characteristics and ability to provide Ecosystem Services. Most Ecosystem Services depend on the shallowness and mangrove survival.</p> <p>The same accounts for onshore activities, polluting the area, and the alteration of flow in the area by structural elements.</p>
<p>Île aux Bénitiers lagoon (Coral beach)</p>	<p>The lagoon is scattered with coral patches and seagrass beds and is surrounded by fringing coral reefs. On the north eastern side, a deep channel cuts into the lagoon, with on the other side the Grand Rivière Noire locations.</p> <p>Because the lagoon is shallow, and there is a large presence of coral reefs</p>

	<p>and sea grasses, dredging in the area would be greatly harmful to the ecosystem and its services. The area is assigned an environmentally sensitive status, because of the aforementioned vulnerable ecosystem elements.</p> <p>A marina in the area would require some structural protection against (storm) wave action and for reachability, which would have a positive as well as a negative effect on the ecosystem. It alters flow in the area and directly affects the area it is built upon, but would create conditions for new corals to grow, and fish to breed.</p> <p>The direct presence of boats and (onshore) activities would be stressful to the more vulnerable parts of the ecosystem, but it has to be acknowledged that already tourists and local fishermen make use of the area, and to do that in a more controlled way (with for example, fixed mooring buoys or a dock) could relieve currents stresses in some way.</p>
<p>Le Morne peninsula (Coral beach)</p>	<p>Similar to the Île aux Bénitiers lagoon, the area is characterized by shallow waters, coral reefs and sea grasses. Furthermore, this area already knows a large share of tourism activity from resorts and hotels.</p> <p>Critical points of a marina development in this area are the inevitable dredging requirement, the need for structural works and the added source of pollutants from onshore activities.</p>
<p>Îlot Fourneau lagoon (Coral beach)</p>	<p>For this area, as well as for the Baie du Cap area, which are both located at the Southern shore, there is a need for considerable structural works to protect against southern swell and wind waves. The structural works and construction thereof will be a critical point for a marina to be developed in these areas.</p> <p>For the Îlot Fourneau lagoon, the large patches of sea grasses provide various regulating and maintenance services. Also, the area knows coral patches and a fringing reef supporting different ecosystem processes and life cycles.</p> <p>The lagoon is shallow as well, indicating a need for dredging works to allow boats in the lagoon and to the marina. As for other 'coral beach' areas, this has a large harmful effect on the ecosystem and should be avoided.</p>
<p>Baie du Cap (River mouth)</p>	<p>Baie du Cap knows a river outlet and an accompanied deep access. As stated before, some severe wave attack may be expected at this southern location. It will therefore require some structural defence works. However, this is likely to interfere with river discharge flows and therewith, sedimentation patterns and flood protection levels.</p> <p>Other than the river obstruction, potentially causing problems for the river as well as the marina, focal points are the onshore activities, potentially causing excess nutrients, noise pollution etc.</p>

Type/size marina



Every ecosystem is deemed to have a certain capacity of anthropogenic action. This could be sailing boats, motor boats, diving trips, fishing, anchoring, boat/human wastes, noise or other anthropogenic effects there may be. These actions influence the liveability and persistence of species and ecosystems, which is different per area. It also depends on how conscientious visitors handle their presence. Some studies have elaborated on this for other areas of the world, with no generic conclusions (Glasby, 1997; McAllister *et al.*, 1996; Warnken *et al.*, 2000). The shared conclusion

is that it depends on many factors in an area, and the characteristics of the area itself. Excess nutrients for example, may be deposited by numerous sources in an area, at different locations, and this area can be able to cycle these nutrients to greater or lesser extent through flora or current actions. It is a complex system to consider, and as such, needs to be considered per case.

An important aspect of determining the maximum allowable influence of a marina is the assessment of the cumulative impacts in a given area, as the example of excess nutrients shows. This is one of the main principles of ecosystem-based coastal zone management (refer to Part I). The principle implies that not only the marina impact has to be determined, but that also the impacts that other developments and activities in the coastal zone have on the considered spatial scale, like the impacts of hotels, resorts, recreation and commercial boating, need to be considered. The impacts need to be considered on the coastal zone ecosystem level.

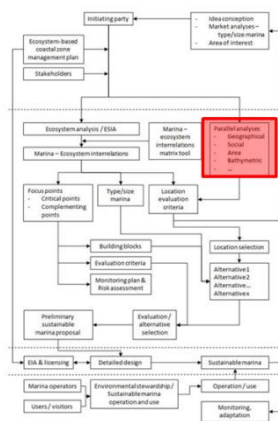
For this case study, one knows that the considered ecosystem features some delicate elements, like coral reefs and mangroves. These are subjected to the anthropogenic impacts of the marina and others. Also endangered species, key species or necessary conditions for a healthy ecosystem may be impacted and lead to deterioration. Already, for Mauritius, environmental reports conclude that the anthropogenic effects are great in the lagoon areas (Government of Mauritius, 2013; Ministry of Environment & Sustainable Development, 2011). It is the reason why a coastal zone management was introduced.

The marina itself will impact through its onshore activities, the physical and non-physical presence of structures and regular activities on the water, around the mentioned ecosystem elements. In this report, no exact estimate for size of a marina can be given. This needs to be modelled and considered by an expert committee. However, sensible choices can be made, based on conscientious reasoning. The type of the marina is wanted to be a recreational, eco-tourism-aimed facility. This leads to a fair estimate on the type of sailing boats, motor boats and their respective actions. As the numbers proposed in the market analysis, are no large numbers relative to other marinas, and for a large part

are already existing users in the area, these numbers are estimated to be acceptable. A remark made, is that another principle of ecosystem-based management applies, once the marina is in place. The principle of 'embracing change, learning and adapting' will imply elaborate monitoring of the impacts in the area, and will deliver insights on the effects the marina and its use will have on the environment.

Per area, different focal points have been named, based on the marina – ecosystem relations. These focal points will apply for the monitoring plans as well.

Parallel analyses



Focus in the framework is the relation a marina development has with its environment. The ecosystem – marina relation has been charted in the previous paragraph. This paragraph however, brings other essential analyses forward. A market analysis, bathymetric analysis and a more detailed hydrodynamic analysis amongst others. In reality more analyses would be undertaken, dependent on the setting that the marina development takes place in. Only the more applicable analyses are briefly discussed below.

Market analysis

An integral part of the development process is an analysis of the market that the proposed development would contribute to. The marina developer's goal is to have a commercially viable marina, based on eco-tourism and sailing activity. It looks to host tour operating organizations and also a boat charter business, which is new to the Mauritian island.

From the Ministry of Tourism, statistics have been obtained on the number of pleasure craft present in the South West region and other regions. Also the types of boats have been specified. The data stems from 2005. Of the total 3,200 boats, around 700 (20%) resided in the South West region. Of this group, a third was being used for commercial purposes and the other two third was privately owned. 90% of the South West boat population did not go further than 8 nautical miles offshore and did not exceed 12 meters of length. A small number of boats, 20, were more than 12 m of length and did go offshore. From a national perspective, one can assume a similar popularity of the region today. According to interviews with local sailors from the island, the boat population has grown marginally over the years.

The marina should not only accommodate the local boat owners, it also aims to offer berthing area for visiting yachts, either from round-the-world sailors, or visitors from another location on the island. Especially if a boat charter business is settled in on the island, visiting yachts can be expected.

From an Indian Ocean perspective, nearby islands and archipelagos offer a good point of reference. Although these locations may have different features, a marina industry and thousands of yachts can be witnessed on nearby Réunion and to the North, the Seychelles. Differences include a shallower coastal zone in Mauritius, a cyclone season during winter months and a lack of sailing destinations. These features do not put off the marina potential in Mauritius, as the island of Mauritius does offer a close-to-perfect sailing climate, beautiful and varied coasts with lagoons, islets and bays and a great tourism scene. Mauritius may not develop a similar situation to the Seychelles, but definitely is missing out on a good share of yachting business.

Accumulating information, a selection of boats may be expected to form a customer base for a marina in the South West region of Mauritius (Table 16). The numbers have been complemented with general sizes and boat specifications.

Table 16 – Prediction on marina customer base

Type of boats	Type specification	Number of boats
Small boats	3 – 5m LOA, draft 0.5 – 1m	80 – 100
Medium-sized boats	5 – 8m LOA, draft 1 – 1.5m	40 – 50
Large boats	8 – 15m LOA, draft 1.5 – 2.5m	30 – 50

Within the South Western region, one can distinguish some different boating areas. The lagoon of Île aux Bénitiers is most popular, with moorings along the coast, around the island and at the Rivière Noire locations. Very little boating activity is found south of the Le Morne peninsula. At northern locations, near Tamarin and Flic & Flac, where some boats are moored. The largest boats are found to be around the Grand Rivière Noire area. The reason for this spread is the larger availability and vicinity of boating destinations, see also the reachability and destination analysis.

Bathymetric analysis

The South West region is characterized by its two large lagoons. The lagoons are generally very shallow (ranging from 0.5 – 1.5 m). There are channels around the Rivière Noire area that cut through the reef and have been naturally created by tidal forces and river discharges. Besides the channels there is deep water to be found near the river mouths.

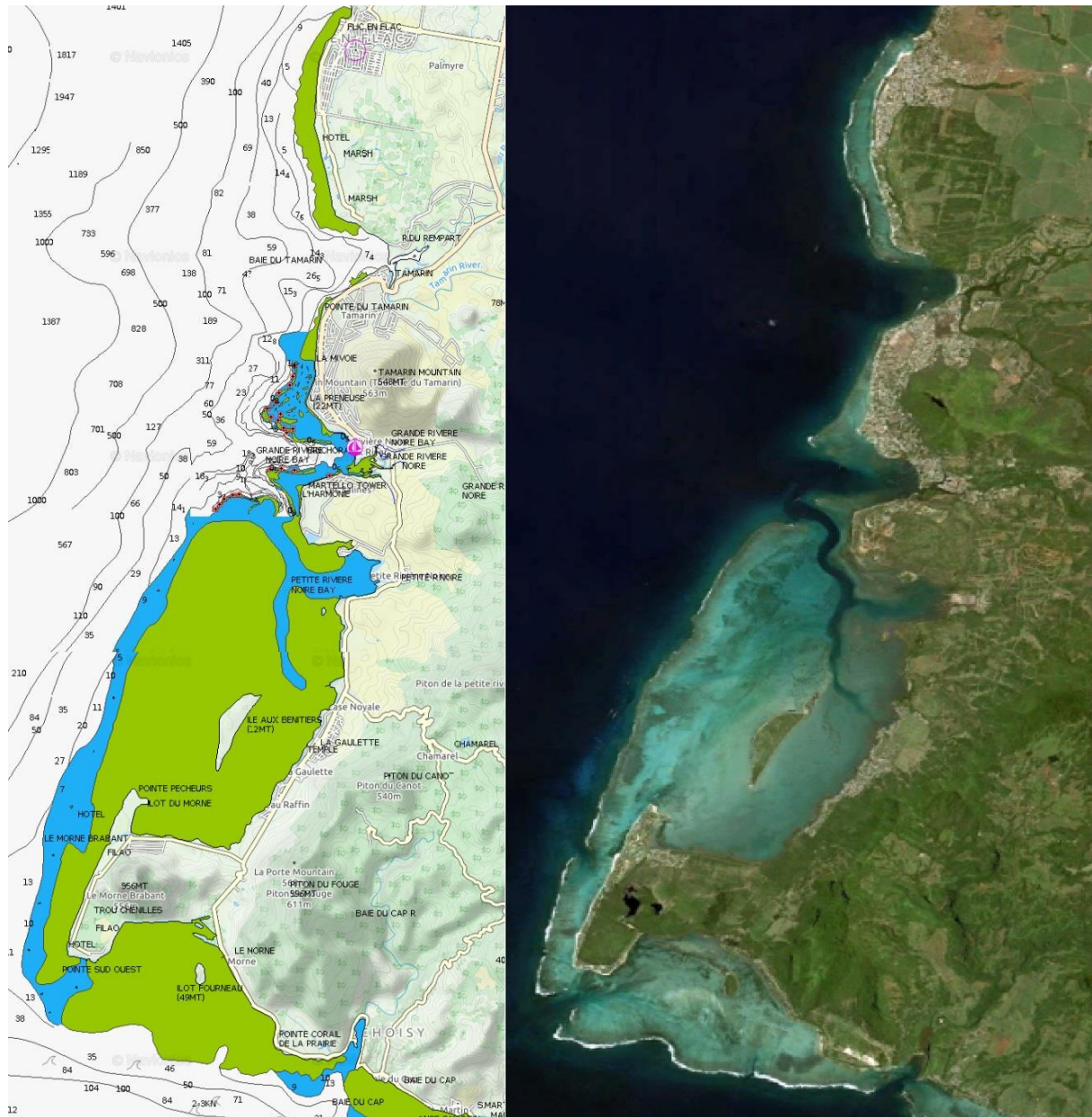


Figure 29 - Bathymetric overview of SW region (source: Navionics Boating 2015, Google Earth 9/2016)

To look into the three sub-regions, the following can be stated regarding their bathymetry. Uncertainties are also acknowledged, as there are some in the area. Also, a rough indication of the bottom type is given.

- 1) 'Coral beaches'. As indicated in the typical sub-region features, the sub-region presents shallow areas. In Figure 29, this has been indicated by the green colour, and the light-blue colour in the Google Earth footage. Depth varies here, depending on the presence of coral reef or -patches, and morphodynamics in the area. In some parts, the sea bottom even emerges at low tides. In general, depths for the sub-region are 0.5 – 1.5 m. With a mean average of 1.0 m for further assessments. The sea bottom is inhabited by (dead) corals, sea grasses or patches of sand, roughly equally divided. The bottom has a hard (carbonate) substrate, making for difficult dredging.
- 2) 'River mouths'. The bathymetry in these areas is more diverse. Deep channels have grown naturally, under the influence of river discharges. These channels range from 2 – 20 m of depth. At the same time, river deposits have created shallow or even emerged areas close to the river mouth (0 – 0.5 m). These sediments are often muddy and silty and may also be carrying nutrients and other run-off effects from the river catchment area. Some seagrass patches may exist on the deeper areas of the sub-region, in the channels. Corals generally do not occur, by the depth, salinity and turbidity parameters of the area.
- 3) 'Mangroves'. This area knows three different settings in the South West eco-region, being a combination with a river mouth and consequently, deep water, a combination with deep water but no river mouth and a type of 'mangrove' area with shallow waters. The latter would be a typical mangrove sub-region. A sediment rich area, with moderated hydrodynamics and a salinity level suitable for mangrove growth. Sediments are of a mixed nature, depending on the area's vicinity to coral areas and river discharges.
 - a. River discharge, deep water; depth varies between 0.5 – 5 m, sediment consists mostly of river deposits (Grand Rivière Noire)
 - b. Deep water, no river; depth varies between 0.5 – 5 m, mixed sediment (50/50 river deposits/carbonate sands) (Petite Rivière Noire)
 - c. Shallow water, no river; depth varies between 0 – 1 m. Here, sediments are mostly originating from coral areas. (Case Noyale – La Gaulette)

Area analysis

So far, the area has been classified on its ecosystem status, and corresponding ecological features. In the area analysis, the area is looked at from an ownership perspective. Some areas in the region have been densely populated (residential), whereas others have been fully developed with hotels or resorts (tourism) and others are free of any development (free). Also, some areas may not be ideal to build, as land may feature rocky shores, soft marshes or steep slopes.

The eco-region can be subdivided the same way as it was done to determine the sub-regions. Per coastal stretch the development will be stated, together with its characteristics, as can be seen in Table 17. Free land is owned by the state, and governed by the Ministry of Housing and Lands. Developed land is practically always owned or leased by private parties, which have a license for the land use they currently practice. To change land use, by for example replacing a sugar cane field with a hotel, a license needs to be obtained by the Ministry.

Table 17 - Area subdivision - Land use

Area (sub-region)	Land use	Remarks
Flic & Flac (Coral beach)	Tourism, residential	Fully developed
Tamarin Bay (River mouth)	Tourism, free	Free land area at northern side
Grand Rivière Noire (Mangrove, river)	Tourism, residential	La Balise Marina
Petite Rivière Noire (Mangrove, deep)	Free, agriculture	Salt plains present
Case Noyale – Le Morne (Mangrove, shallow)	Free, residential	Two small villages, and otherwise free. Underdeveloped
Île aux Bénitiers lagoon (Coral beach)	Free, environment	Eco-resort plans, pressure zone
Le Morne peninsula (Coral beach)	Tourism	Fully developed along the beach
Îlot Fourneau lagoon (Coral beach)	Free	No development, steep slope
Baie du Cap (River mouth)	Free	Road around bay, steep rocky slope

When fully developed, little land area is available for marina development. In such a case, it might be an option to move seaward, and create additional land area. For this case study, it is assumed that current fully developed land offers no option to adapt to a marina facility.

Reachability and destination analysis

This analysis considers the connections the marina makes on land, regarding infrastructural networks, as well as destinations on the marine side of the marina. The road network and (coastal) destinations are given below, in Figure 30.

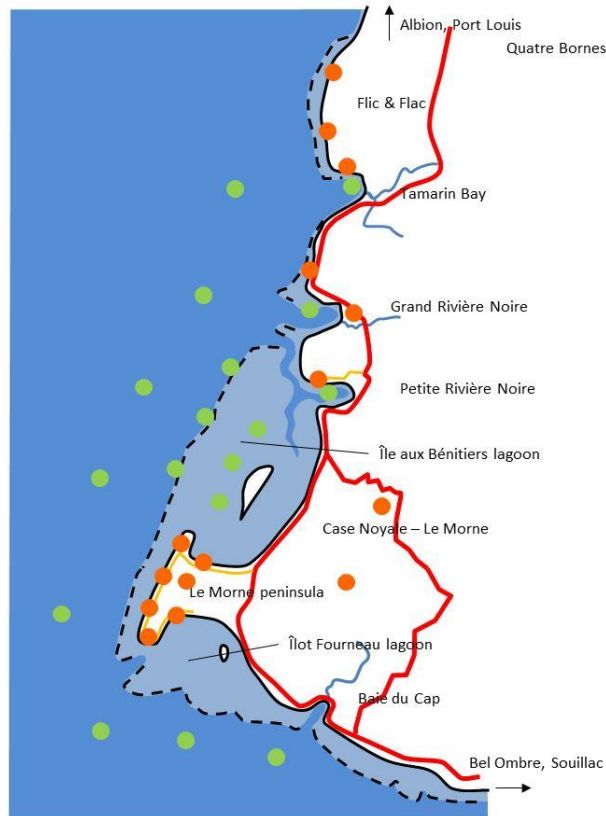


Figure 30 - Reachability and destination overview for SW region (orange dots represent onshore destinations, green dots represent marine destinations)

An important finding is the good destinations profile for all locations considered in the South West area. Within the area itself, there are numerous locations that are currently used for mooring boats (refer to the market analysis). Also, there are many eco-tourism attractions like coral reefs, dolphins, and fishing around the region. Of course, according to current and future legislation, these activities will be monitored and only take place in designated areas. As boating activity has developed over time in the area, the more popular areas are close to the boating destinations like coral reefs, mooring locations and situated in the more calm sea state areas. In this light, the Southern areas are not very well situated. The Southern areas are the Îlot Fourneau lagoon and Baie du Cap.

Outside of the South West area, the most popular boating areas of Grand Baie, and also the Mahébourg area, are to be found at 30 nm distance, which is a regular and easy distance for a day trip. On a larger scale, destinations are South Africa, Madagascar, Réunion, Seychelles, Rodrigues and Asia. These are destinations already in use by round-the-world sailors, which have indicated that Mauritius/Rodrigues is located perfectly on route.

On land, most south western areas are well reachable with existing infrastructure, represented by the B9 motorway. It directly links all locations to important people centres of the Quatre Bornes district, Port Louis and Mahébourg. Sub-regions that do not have a direct connection are the Le Morne peninsula and the lagoon areas (Île aux Bénitiers and Îlot Fourneau). For the two islands, naturally, no land connections exist. The Le Morne peninsula is connected to the B9 motorway by a smaller two-way road, which is often used by visitors of the many resorts and hotels on the peninsula. It is therefore expected to offer adequate capacity for the increased traffic due to a potential marina development.

Within the area, on land, several majestic and renowned touristic destinations can be identified. The iconic Le Morne Brabant and the Black River Gorges National Park are among these.

Hydrodynamic analysis

As introduced in the chapter on general information, Section 8.2 – The coastal environment of Mauritius, there are important hydrodynamic processes in the coastal zone to be considered. There is a tidal range of 0.7 m (Table 5) and three types of incoming waves, causing severe wave attack on the island. Currents are not strong around Mauritius, but cannot be neglected because current cycles are part of the lagoon's ecosystem, transporting and distributing sediments, nutrients, algae and water.

Zooming in on the South West eco-region, one knows that the area is mostly affected by swell from southern directions, and year-round tradewinds from south eastern directions. Also, the South West area may be impacted by cyclones, but more rarely than the northern and eastern coasts, as cyclones originate to the North East of the Mascarene Islands. The wave statistics obtained in Section 8.2 are calculated at the 30 m depth contour around the island. These deep water waves, travel towards the coast of Mauritius, and experience friction from the coastal features. The reefs and lagoons in the considered area have a very large effect on how the waves are attenuated travelling inshore.

The type of reefs that form the outer edge of the lagoons are fringing reefs, and reside only 0.5 to 1 m below the surface, generally and interrupted by some channels. Depending on water levels over the reef, both wind waves, swells and infragravity waves will attenuate over the reef and enter the lagoon. At normal water levels, without surge, wave heights in the lagoons are moderated to a maximum wave height of 0.5 m. This holds for (storm) wind waves, as well as for swell waves. Short period wind waves completely dissipate over the reef, whereas longer wave periods decrease over the reef by 20 – 40 % (Pomeroy *et al.*, 2012). At higher water levels, during surges induced by inverse barometric and set-up effects, water levels over the reef may be 1 m higher, leading to maximum wave heights of 1.0 – 1.5 m and wave periods of 10 – 30 % of their original peak wave period. These conditions have a return period of 50 years (Baird, 2003).

These numbers are wave estimates for the areas that are valid inside the lagoon – behind the fringing reef – only. This applies to all the 'Coral beaches' sub-regions. Other areas, like the 'River mouth' sub-regions, are under more severe wave attack as no reef is present to attenuate waves. However, still some shoaling and refraction will occur, dependent on the geometry of the bay and wave direction. These effects will attenuate the wave action at these locations, but severe wave action may be expected. For the 'Mangroves' sub-regions, the situation is different for each type of 'Mangrove' area. The deeper area will experience severe wave action, unless geographically sheltered, but the shallower area is as well protected by the reefs and lagoon as for the 'coral beach' cases.

The wave height return period as has been indicated by (Baird, 2003) is set for the situation with surge and incoming waves from the 50 year-storm. Outside of these conditions, there is a strong

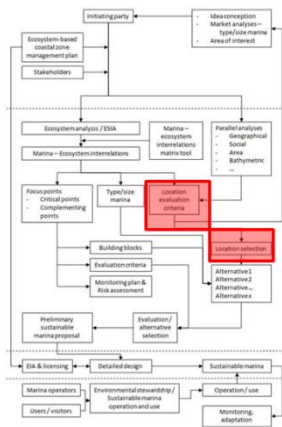
difference between the southern side of the island (from Le Morne peninsula to Baie du Cap), compared to the western coast (from Flic & Flac to Le Morne peninsula), where swell impact is only indirect and typical trade wind conditions are from the land, resulting in very limited wave development.

The following table (Table 18) presents the values that are used for further study per area, based on the reasoning above. For a better assessment, one will need to perform hydrological modelling exercises with more detailed bathymetric and geographical information.

Table 18 - Wave characteristics per area

Area (sub-region)	Wave height (H_s) 50-year return period	Peak period (T_p) 50-year return period
Flic & Flac (Coral beach)	1.0 – 1.5 m	4 – 10 s
Tamarin Bay (River mouth)	1.5 – 3.0 m	6 – 15 s
Grand Rivière Noire (Mangrove, river)	1.0 – 2.0 m	5 – 12 s
Petite Rivière Noire (Mangrove, deep)	1.0 – 1.5 m	4 – 10 s
Case Noyale – Le Morne (Mangrove, shallow)	0.5 – 1.0 m	4 – 6 s
Île aux Bénitiers lagoon (Coral beach)	1.0 – 1.5 m	5 – 12 s
Le Morne peninsula (Coral beach)	1.0 – 1.5 m	4 – 10 s
Îlot Fourneau lagoon (Coral beach)	1.5 – 2.0 m	5 – 12 s
Baie du Cap (River mouth)	2.0 – 4.0 m	7 – 15 s

10.2.2 Development phase – Location selection



The selection of a location for the marina development is an emphasized aspect in the framework, as it has large impact on how the marina affects the area, as well as its success on social and economic grounds. From the ecosystem analysis, as well as from the other parallel analyses, information has been acquired to base the selection on. The decision needs to consider the collective of information.

As shown in the initial framework, there's a feedback loop at this point to the initiating concept of the marina. In case no location in the South West region suits the ecosystem-based coastal zone management plan, or any of the analyses excludes the considered area for marina development, the feedback needs to be given to the initiating party, who can decide to let go of the marina concept, or change focus to another area.

For the case study, this is not the case, there are options for marina development in the South West region, as the collective of analyses does not exclude all areas.

In Table 19, the information of different analyses have been collected and registered per area. A very positive score (++) indicates that a marina development at that location well fares with the specific analysis for that area. A very negative score (- -) shows that a marina development does not align with the findings from that analysis. It does however not say that a marina development is impossible for reasons of that analysis. For example, although a marina development at Tamarin Bay received a very negative score on the hydrodynamic analysis, because of the little natural shelter and deep waters, it is not impossible to create a marina in this location. Relatively large structures would be needed.

Table 19 - Location evaluation

Area	Ecosystem analysis	Hydrodynamic analysis	Area / Land use analysis	Stakeholder analysis	Reachability / Destination analysis		Bathymetric analysis
					Land	Sea	
Flic & Flac	+/-	-	--	+/-	+	+	-
Tamarin Bay	+	--	+/-	+/-	+	+	++
Grand Rivière Noire	+/-	+/-	+/-	+/-	+	++	+
Petite Rivière Noire	+	+	+	+	+	++	+
Case Noyale – Le Morne	-	+	+	+	+	++	--
Île aux Bénitiers lagoon	--	+/-	+/-	-	--	++	--
Le Morne peninsula	--	-	--	+/-	-	+/-	-
Îlot Fourneau lagoon	+/-	-	+/-	+/-	--	-	--
Baie du Cap	+	--	--	+/-	+/-	-	++

From the table, a location selection can be made. Although different analyses may be rated differently, one area is deemed most appropriate on grounds of most of the analyses findings. The Petite Rivière Noire location is rated positively on all analyses, not being discouraged by any analyses.

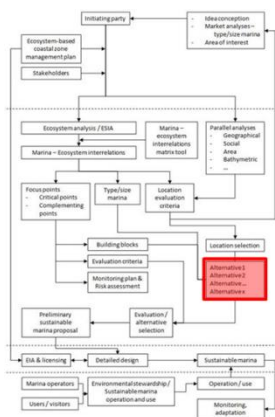
To elaborate on the scoring for this area, the different scores will be briefly elaborated below.

Petite Rivière Noire area

- Ecosystem analysis (+): The mangrove area presents challenges to development in the region, but the Petite Rivière Noire location offers the right conditions (shelter, deep water, no river discharge) to be able to accommodate a marina in the area, in co-existing with the mangroves and other ecological features in the area.
- Hydrodynamic analysis (+): The area enjoys natural shelter from the coral reefs of the Île aux Bénitiers lagoon, the geometry of the bay and bathymetry. Mangrove shores also, aid in the wave attenuating qualities of the area.

- Area / Land use analysis (+): The area offers a lot of 'free' space for development. Currently, abandoned salt plain areas are looking for a different use, and other forestry area is available for development, under rule of the Ministry of Housing and Lands. Notion has to be made of mangrove presence, which is highly valued from an ecological, as well as a social point of view.
- Stakeholder analysis (+): Stakeholders from commercial backgrounds see potential for a marina at this location for its reachability and destination potential, available area and market forecasts. Socially, the marina could provide a much needed centre for communal activities. A marina would also contribute to the area, directly by attracting interest to the area and indirectly, by development of the surrounding area by additional development. As the area develops, higher standards on sewage, drainage and housing will apply, relieving stress on the environment amongst others. On the crossover, socio-economically, the marina may provide an important share of job opportunities and well-being for local communities.
- Reachability / Destination analysis (+ & ++): By land, the Petite Rivière Noire location is well reachable and links well to other parts of the country. The B9 highway runs North – South along the area, directly linking the Northern areas of Quatre Bornes, Port Louis and touristic areas of Flic & Flac and Tamarin with Southern areas of Le Morne, the Black River national park and the southern coast. From the sea, the location is well reachable by existing deep channels. In the direct area, numerous (eco-)tourism areas are available. For coastal trips, relatively big sailing hubs of Grand Baie, Port Louis and Mahébourg are within day sailing distance and well reachable in predominant weather conditions.
- Bathymetric analysis (+): Bathymetrically, a deep channel reaches to Petite Rivière Noire. The deep channel is bordered with shallower lagoon areas. This is a good setting for a marina development, as the combination delivers access as well as protection against wave ingress, surges and currents. Close to shore, however, some very shallow areas are witnessed, created by terrestrial sediments being held by mangrove areas. This may pose some dredging requirements with associated impacts/risks.

10.2.3 Development phase – Alternatives



The location evaluation led to the Petite Rivière Noire area for a marina development. In this section, alternatives for a marina in the area have been developed. Following this section, will be the selection of the preferred alternative. The preferred alternative will be selected by reviewing the different alternatives, including the ‘no development’-option, where the original situation is considered. For the alternatives, two different marina concepts are given. For each concept, there are two options available; there is the ‘traditional, single value’ situation, where

conventional techniques are applied, focussing on a limited selection of values (functionality, cost). For example, a hard structural element could be applied, rather than a floating, or piled structure when that is a more cost-effective or more functional solution. Also, onshore activities may not be controlled and regulated as much as they would for an environmentally conscious situation. So, next to the ‘traditional, single value’ option, there will be its counterpart, the ‘nature-based, multi value’-option. The latter option naturally incorporates techniques, measures and available knowledge to integrate the marina in its natural, societal and economic environment.

In total, there will be five alternatives to be considered for evaluation;

- ‘No development’; Original Petite Rivière Noire area,
- ‘traditional, single value’ Petite Rivière Noire concept 1,
- ‘nature-based, multi value’ Petite Rivière Noire concept 1,
- ‘traditional, single value’ Petite Rivière Noire concept 2,
- ‘nature-based, multi value’ Petite Rivière Noire concept 2,

First, the ‘no development’ option is outlined, followed by marina concept 1 and concept 2. Per concept, the traditional and the nature-based options are considered.

To elaborate on the difference between a ‘traditional’ and a ‘nature-based’ design, the essence can be found in the scope of the different approaches. Whereas for traditional design functionality, cost-effectiveness are dominant values in design considerations, nature-based design takes into account the full spectrum of values that the marina may have or influence. Integration of a marina in its natural and societal environment for example; natural and local processes are stimulated and enhanced, to create added value. Also, in this research report, the marina development has been linked to sustainable coastal zone development. The marina influences the sustainability of the coastal zone, and this is a value that is taken into account as well. Nature-based design is therefore said to be ‘multi value’-design, where traditional design is named to be ‘single value’-oriented.

No development alternative

For the 'no development' alternative, nothing changes to the existing situation in the Petite Rivière Noire location. No marina is being implemented. This implies a few things to the area, which apply at the moment of writing to the area. From the stakeholder analysis, it has become clear that the area is currently experiencing some regional problems. From the community group, represented by local inhabitants and fishermen, the regional council and regional environmental health groups, these problems were named as follows; little integration of local communities in area development projects, underdeveloped villages and facilities, water quality issues by domestic sewage and run-off and a lack of environmental awareness with young generations.

Additionally, local fishermen may currently have problems regarding their equipment, by not having a safe, sheltered area to moor their boats, and a lack of a platform to sell their catches to passing visitors as well as local people.

In the Petite Rivière Noire, rehabilitation of mangroves has successfully taken place over the course of 2011, by an NGO that is active in the area. The goals are the improvement of coastal resilience and community livelihood. Current endeavours, like the planting of mangroves, are assumed to continue, supported by international sustainability funds and local governments.

The region of Petite Rivière Noire is depicted in Figure 31. On the left, the deep channel can be seen, entering the area. There is a shallow area at the top left, with Îlot Fortier on its right. On the right side of the area, the village of Petite Rivière Noire and salt plains can be seen. Mangroves have been planted on the southern shore as well as around the tip of the salt plains.



Figure 31 - Petite Rivière Noire overview, no marina development

Petite Rivière Noire concept 1

The first marina concept involves the redevelopment of the salt plains area. The current activities on the salt plains are on a heavy decline and have lost its use. From the site visit, the intentions of the land owner are known. The land owner has asked consultancy firms to find a better use for the area, and one of the options has been named to be a marina. Development plans however are in an early state. Slowing the progress are costs associated with an EIA procedure and the licence to change land use.

Figure 32 shows a general location and configuration for the marina, largely using existing land structure and evading impact on mangroves.

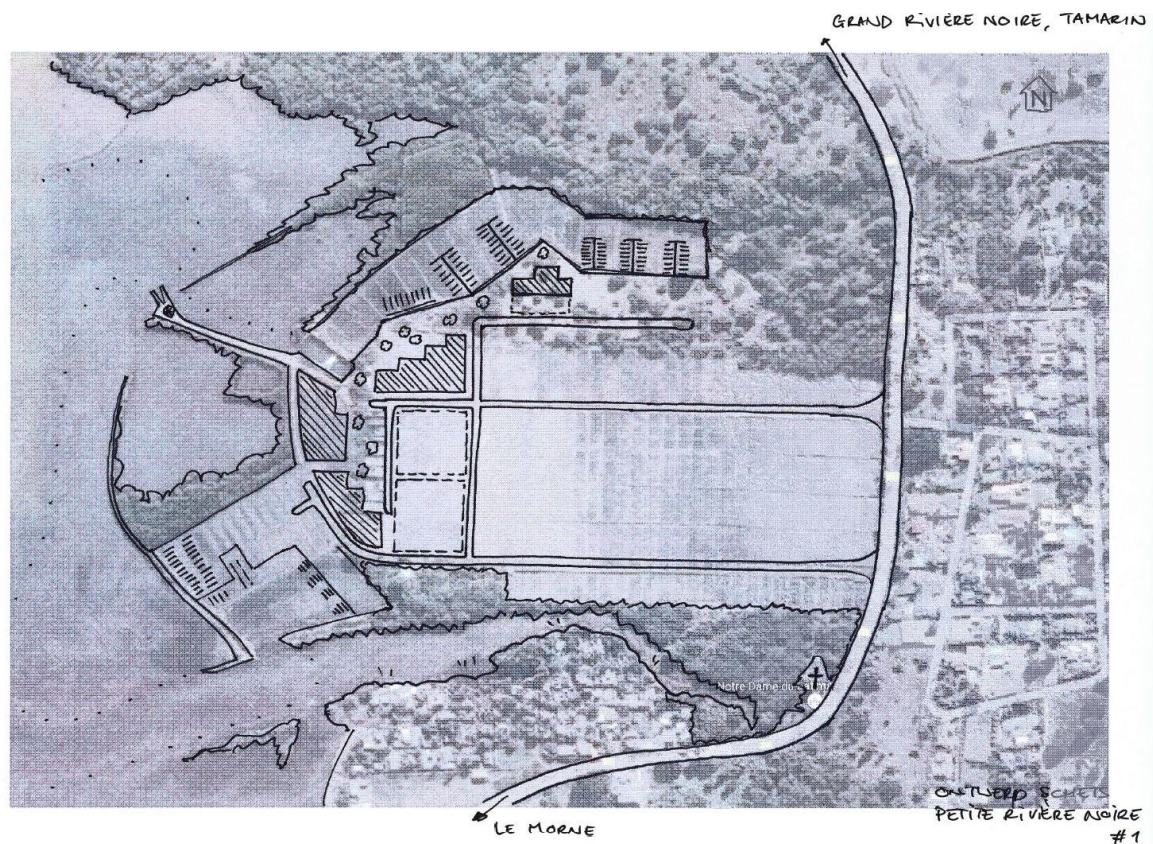


Figure 32 - Petite Rivière Noire marina concept 1, scale 1:2500

The dotted marks on the left side of the drawing indicate the deeper water and access channels. There are two marina basins; the northern basin would be used for recreational and visiting yachts only. The bottom one is aimed at providing service areas and will offer facilities for fishing boats. Shaded buildings are market areas, communal areas, marina offices, shops, restaurants and such. On the right side of the drawing, one can see the B9 motorway, being the main route for North-South traffic along the coast. The marina basin's area will be excavated to create the basin and guarantee sufficient depth. The land can be used to fill the exterior salt plain area, to be able to develop the area in due time, with residential, commercial or other types of purposes.

'Traditional, single value' option for PRN concept 1

In a traditional approach to development of the marina, the marina may not exactly be organized in this way. The drawing in Figure 32 shows, for example, that existing dams and ridges to separate mangrove area and salt plains are used. Without considering the natural processes, supporting the environmental consideration to leave the natural area intact, the area offers valuable area for (marina) development. The marina may have incorporated the mangrove area as well, for functional and economic reasons. Incorporating the mangrove areas would require less excavation costs, imply less navigation and increase marina area. It does however, delete the mangroves and hence deletes the Ecosystem Services the mangroves provide directly, and indirectly, through the support the mangroves offer to other parts of the ecosystem.

Another important aspect of a 'single value' marina development would be the lack of control and regulation of the effects of onshore activities. Storm water run-off, sewage control and the release of excess nutrients, oils and fuels into the marine area are notable impacts a marina may have on its environment. These influences impact the water quality of the marina, the liveability of the basin for flora and fauna in – and out – the basin and a range of other aspects of the surrounding environment. There are numerous practices known, measures to be implemented, to abate the release of these materials into the marine area. For example a drainage system, filtration of water or regulation on the use of potentially toxic materials in boat yards, can cancel the aforementioned effects. This accounts for practically all marina developments. Good guidance is offered by a series of sustainable marina operation initiatives, as were mentioned at the beginning of the report, in Part 0.

Additionally, the 'traditional' marina option may include hard structural elements for their docks, or quays when there are financial or functional reasons for this. Functionally, for example, a fixed jetty would offer more secure mooring, with less movement and less risk of breaking. A fixed jetty however, as was learned from the marina – ecosystem interrelations, does have a generally bad impact on its natural environment. Floating elements however, may offer less – but adequate – functionality, but also impacts the environment less heavily and even supports the ecosystem in certain ways. Floating elements therefore will make an appearance in the 'nature-based'-option for the same marina concept.

A 'traditional' marina option may also choose to minimize social- and communal areas, to limit building operations and associated costs. This way the beneficial, enhancing effects these areas may have, according to the ecosystem assessment, may well be missed, therewith missing an opportunity to find a synergetic solution for a marina development in the Petite Rivière Noire area.

'Nature-based, multi value'-option for PRN concept 1

In the case where the marina development is done with elaborate assessment of the relation the marina may have with its environment, the 'nature-based'-option can be found. In this option, positive interrelations between the marina and its environment are acknowledged and applied in the marina design. Negative interrelations are known and avoided, and where needed, mitigated to decrease the marina's impact on the environment.

For the PRN concept 1 this means that the mangrove areas are left intact, not directly impacted by marina developments. Indirectly, there will be interrelations between the mangroves and the marina, both positively and negatively. On a positive note, the mangroves are known to hold sediment, to cycle nutrients (purifying water), cleaning air and offer habitats to species that are important for biodiversity and ecosystem resilience. The mangrove area also supports the nearby coral regions by aforementioned sheltering and habitat (nursery) areas. Having the mangrove area in between the marina basins and the surrounding environment may therefore be very beneficial to the marina. On an accompanying negative note, the holding of sediment, together with the sensitivity of the mangroves, induce challenges to the marina. The sediment may accumulate in the waterways, limiting water depth and therewith access. Also, if the marina impacts the area in such a way, that basic conditions for mangroves are not met, the mangroves may disappear, with self-evident negative impacts to the natural environment.

For a 'nature-based'-option, environmental stewardship is applied in all aspects of design. Onshore activities will be monitored and any effluents, pollutants or wastes will be controlled, prohibiting it from reaching the marine area. As onshore activities can have a very negative impact on mangrove ecosystem health (see Table 14), the application of best practices, measures and programmes on sustainable marina use are adopted in the 'nature-based'-option.

As explained for the 'traditional' option for a marina at Petite Rivière Noire, the 'nature-based'-option should choose floating elements over solid structural elements. This would benefit the marina basin by allowing more circulation of water, potentially purifying of water and the creation of additional habitat. Numerous options already exist, that have proven a valuable addition to floating docks (Deltares *et al.*, 2013). The downside may be less functionality, or protection level, as discussed. However, for the marina lay-out given in Figure 32, these downsides are not important, as there will be calm waters inside the basin.

Petite Rivière Noire concept 2

The second marina concept for the Petite Rivière Noire is located roughly 800 m to the North East of the concept 1 location, and finds itself just to the West of the small island of Îlot Fortier. The marina area is half on-land, and half off-land, implying some excavation and dredging works to take place. The existing bank is shallow and accommodates some scattered mangroves. On-land, the area is free of any development. It is a bushy area, which is state-owned.

The marina basin is square, with a wide pier on the western side (left in the picture). Fishery activities take place at the other side, leaving the marina basin for pleasure craft. In the top right corner of the basin, there is a haul-out service, and a service area. Around the basin, facilities are located. On the pier, a good setting for social activities, a yacht club and charter services is present.

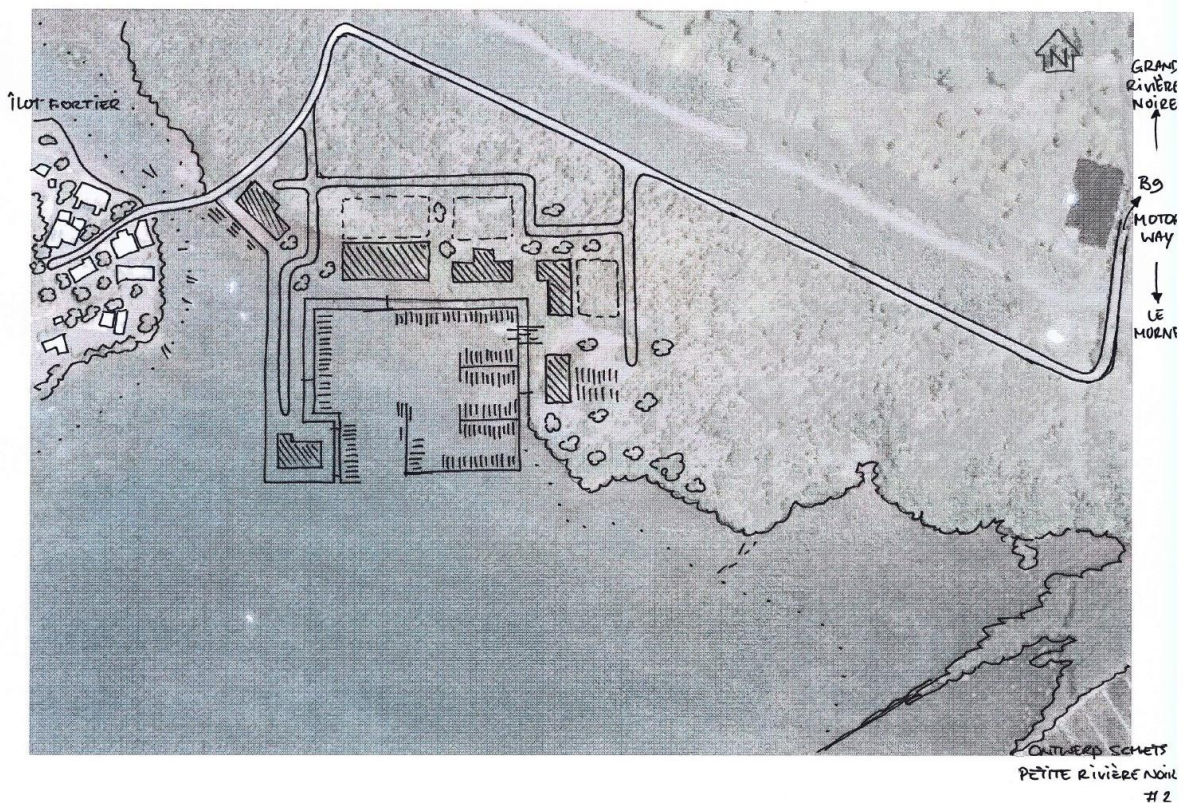


Figure 33 - Petite Rivière Noire marina concept 2, scale 1:2500

The location connects to the B9 motor way by a small road. The motor way connects the area with northern cities and destinations, as well as it connects with the southern areas.

The marina entrance is located at the deeper zone of the area. It links with the channel, going offshore through the reef (see Figure 31 for the deep channel at Petite Rivière Noire and Figure 29 for the bathymetry of the region). Hydrodynamically, the location is strategically oriented for incoming waves and currents. The small island, the local bathymetry and the geography of the region are the reasons for this.

'Traditional, single value' option for PRN concept 2

In the hypothetical alternative option for a marina in the South West eco-region, is the marina concept 2. For the 'traditional' option, the concept marina is designed from a 'single value'-point of view. For the PRN marina concept 2, this would mean limited control and regulation of onshore activities, like in the traditional option for concept 1. Another parallel between the two 'traditional' options would be the use of solid structural elements. Not focussing on natural processes, the pier on the western side could be a solid element, perhaps by use of caissons, or sheet piling. Actually, besides the wide pier, also the outer docks and quays could be solid and fixed in position. The structural elements would drastically block and deviate flows in the area, inducing still-standing water, and deteriorate water quality by a lack of circulation and disruption of the ecosystem's capability to purify water. Stability of the elements would be better though, and more resilient against heavy weather action. A solid structural element has great wave-attenuating characteristics, which improves the marina user's experience by lowering wave heights in the basin.

The lay-out of the on-shore area in the 'traditional' option would also involve more closely built areas, with a lot of paved area. Little space for grass, bush or trees would be incorporated in the design, as this would be less functional than a fully paved parking lot, or added buildings. This can actually be witnessed at the one, and only, public marina of Mauritius in Port Louis. The increased paved area has a negative impact on the way storm water finds its way to the sea, the terrestrial ecosystem and also on the eco-tourism character of the marina. The latter would affect the customer base for this marina development, as eco-tourism is focussed upon.

Lastly, congruent to the 'traditional' option for concept 1, the 'traditional' option may miss out on the beneficial effects that social- and community places may have. The pier actually offers a great location to practice educational programmes, or to showcase the elements of the surrounding ecosystem. A large yacht club, restaurant or other use of the area may deliver larger returns, but is then traded for ecological benefits, which may make marina profits more sustainable as water quality will be improved.

'Nature-based, multi value'-option for PRN concept 2

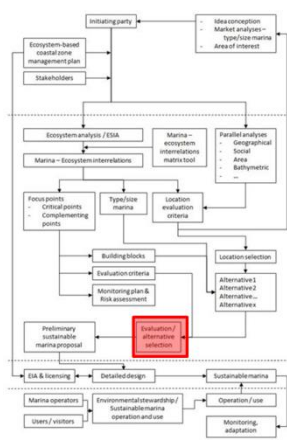
For the 'nature-based'-option of marina concept 2 one takes into account the lessons learned from the ecosystem assessment. The marina – ecosystem interrelations matrix for Petite Rivière Noire is given in Table 14 on page number 127. The 'nature-based'-option takes into account best practices and measures to improve the relation between the marina and its ecosystem, so that the marina can support and enhance natural and local processes.

Solid structures are avoided as much as possible in this design. Solid structures that are needed, at the northern and eastern end of the marina, will be fitted with hanging structures, rough surfaces and made of the eco-friendly materials. These solid structures are quay structures, needed to provide sufficient depth in the marina. With the right measures, the solid structure's potentially beneficial effects can be highlighted and negative effects can be mitigated. For the pier, no blocking structure will be incorporated in the design. Instead, as the pier will need to bear significant loads, piling will be favoured. Piles can also be fitted with habitat-increasing measures and do allow flow to pass underneath the pier, into and out of the marina. For any construction in the project, the most environmentally sound practices should be applied, to leave as little marks as possible on the existing sea bed and water column.

In general, the 'nature-based' design should minimize paved areas, excessive structures and increase 'green' areas, as these areas are important features in the processing of nutrients, storm water and other effluents that may harm the marine environment. These effects are captured in the marina use element of 'onshore activities'. This element captures many more aspects of onshore activities, like servicing, cleaning, sewage control, fuelling and many others. To counter any negative effects that originate from these activities (see the double negative scores in Table 14), measures can be applied that control the effects (Epsilon Associates Inc, 2001; PIANC WG149, 2016). Options are filters, drainage systems and regulations.

In the 'nature-based'-option in this location, the circulation through the marina basin can be used in advantage of water quality. Sea grass fields on the marina sea bed should be promoted, as these fields have large capabilities of water purification, de-eutrophication, habitat provision. As sea grasses are vulnerable to dragging anchor chains, the use of these should be minimized by using alternative means of mooring/anchoring of boats and docks.

10.2.4 Development phase – Alternative selection



As stated in the previous chapter, there are five alternative options to be considered for the preliminary marina proposal;

1. 'No development'
2. PRN Concept 1 – 'traditional'
3. PRN Concept 1 – 'nature-based'
4. PRN Concept 2 – 'traditional'
5. PRN Concept 2 – 'nature-based'

The alternatives are evaluated in Table 20 on the following criteria, which are briefly elaborated below.

First, its score for environmental integration, representing the degree of how well the marina design incorporates its surrounding Ecosystem Services, and the impact it has on its environment. For this assessment, one takes the focal points, given in Section 10.2.1, page 129, into account. Socio-economically, the alternatives are scored for the way socio-economical aspects, like area development, community enhancements (through employment and social areas) and increased livelihood, are integrated in the design. Stakeholder interests are also named as an evaluation criterion. The better stakeholder interests are incorporated, the more stakeholder support can be expected and the higher the stakeholder criterion is rated. The marina options are also rated on their functionality, representing the degree of protection against climatologic elements, and the usability of the design option. Another aspect that is important for alternative selection is a rough indication of cost associated with a design. This refers to construction and development cost only. Last, there will be a 'long-term' element in the evaluation process. Long-term perspectives are an integral part of being a 'sustainable marina', the 'long-term' rating reflects the condition of the marina over its lifetime. It considers the predicted condition of certain elements like water quality, community livelihood and regional development around the marina.

Collected, these are the different criteria;

- Environmental integration
- Socio-economic integration
- Stakeholder support
- Functionality
- Cost
- Long-term aspects

Table 20 - Alternatives evaluation scheme

Option	Ecosystem integration	Socio-economic integration	Stakeholder support	Functionality	Cost	Long-term
No development	+	-	+/-	-	++	-
PRN Concept 1 – ‘traditional’	-	+	+/-	++	-	-
PRN Concept 1 – ‘nature-based’	++	+	+	+/-	-	+
PRN Concept 2 – ‘traditional’	-	+	+/-	++	-	-
PRN Concept 2 – ‘nature-based’	++	+	+	+	-	++

In Table 20, the alternative marina options have been evaluated on the aforementioned criteria. In red, the preferred alternative option has been marked. The result is discussed below, highlighting the decisive differences and interesting points.

Ecosystem integration

First, the environmental integration is an important aspect throughout the framework for sustainable marina development. Developing a marina concept where environmental interests are only limitedly taken into account, defeats that purpose. The ‘traditional’ options have been included in the evaluation scheme to show the differences compared to their ‘nature-based’-counterparts. The differences are not only found in the ecosystem integration, but also in the long-term character of the marina. By incorporating Ecosystem Services, and applying knowledge of interrelations to the benefit of the marina (water quality, user experience, and eco-character), the marina will be able to sustain its services for the long-term. Some functionality is lost, however, as for example solid structures and repeated dredging may deliver more guaranteed functionality.

Naturally, the no development option is well integrated with its natural environment. However, both eco-marinas are also integrated in their ecosystem surroundings, and are able to offer important services as habitat provision, sheltered waters and environmental education. Combined with environmental stewardship in boating as well as marina operations, the marina will be undemanding in the ecosystem-based coastal zone management plan. Indirectly, a marina development may

develop its surrounding area, improving its current livelihood and facilities like sewage and storm water drainage. The latter effects are beneficial to the environment compared to the current state and the no development option.

Socio-economic integration

Socio-economically, the benefits of a marina are clearly visible. Where a no development path will not lead to any much-needed employment, or increase in well-being, any marina development, 'traditional' or 'nature-based', will contribute clearly. Part of the design is the understanding that local communities are involved and will be actively incorporated in the marina development. On fishery, the community will have a place to safely moor their boats, and a place to market their goods, both will be beneficial to the local fishery sector. Aside, from direct employment and communal areas, a marina development in Petite Rivière Noire will contribute to the wider region. Tourists are attracted to the area, leading to more tourist-oriented facilities, jobs, earnings and an improved livelihood.

Stakeholder support

As a number of stakeholders with a large interest in a marina development are concerned with the environmental impact marina may have, the 'nature-based'-option can count on more support throughout the layers of society. On a regional level, different environmental groups are actively working to preserve their natural environment. Nationally, the country's vision and legislation applies, both of which are in favour of sustainable development. Legislation even requires a thorough environmental assessment. On other aspects of interest for stakeholders, like return on investment, area development or competing business, no difference of interest is assumed for the different marina options.

Functionality

Functionality is a criterion that has been rated higher for the 'traditional' options. As elaborated in the respective 'traditional' designs, the use of solid structural elements and 'practical' building, may contribute to functionality, but is often done at an environmental cost. As long as decent safety levels can be guaranteed and proper organisation applies at times where dangerous situations arise, less functionality and improved ecosystem integration is preferred. The no development option has been scored a double negative (- -) as no functionalities are enhanced or added to the area.

Cost

The cost for a 'nature-based' option may initially be higher than a 'traditional' option. The 'nature-based'-option requires more detailed assessment of the natural surroundings, potentially more sophisticated measures to enhance or mitigate certain effects and a continued monitoring scheme.

However, on a longer term, less financial means are needed to maintain the marina, and its environmental state. There are numerous examples in practice where environmentally sound marinas have clear monetary value and economical benefit (Epsilon Associates Inc, 2001; Neil Ross Consultants, 1996). However, as a considerable investment is needed for all marina options, a negative score (-) has been given.

Long-term

In the last column of Table 20, the long-term element has been considered. There are significant differences to be seen for this criterion for the alternative options. The element will be considered per option below.

First, the no development option, considers the current situation with no marina development. As current trends are a declining ecosystem, by predominantly non-point source pollution (domestic sewage, contaminated storm water run-off), the forecast for the region is a further deteriorating environmental status. A lack of area- and community development is the origin of the problem.

A marina development would have a strong beneficial effect on its surrounding area in terms of social and economic terms. It would develop the area, with control of current pollution sources, by indirectly supplying the means to implement a sewage system and proper drainage, together with an increase in environmental awareness. In the long-term this will be a very positive effect.

However, if a marina is built with little consideration of the environmental challenges, the marina may become yet another source of pollution and ecosystem degradation in due time. To prevent this, the 'nature-based'-options are introduced. The 'nature-based'-options for marinas seek to develop the area so that current negative trends are halted, whilst being aligned with the natural environment it is built in, both in the short- and the long-term.

There is a difference between the two 'nature-based'-options though, as the marina locations differ. Concept 1 is located at the current salt plains area, which is not a great use for the area. A marina in this area would be much better use, socially and economically. However, by preserving the existing mangroves, the entrance channel to the marina is narrow (50 m) and the marina basin is long-stretched. As stated in the design paragraph, the mangroves close to the entrance channel, may present a potentially impactful dredging need. Also, a lack of circulation may be expected, with negative consequences to water depth through siltation and water quality through the accumulation of nutrients and any hazardous materials.

Considering all criteria, the preferred alternative is the 'nature-based'-option for the Petite Rivière Noire marina concept 2.

11. Framework enhancement

In the previous chapter, Chapter 10, the initial framework has been applied in a case study for a marina in Mauritius. The framework started at the basic idea from an initiating party and concluded with a preliminary sustainable marina proposal. Follow-up steps are the design phase and ultimately the operation phase. Guidelines for design considerations and operations are represented in various guidelines across the world, and assisted by a number of accreditation schemes, are increasingly being applied in practice.

The initial framework provided guidance to the prior phases of marina development, the initiating phase and the development phase. This framework has been ecosystem-based, focussing on the relations that exist between a marina and its natural environment.

Throughout the case study, inadequacies and improvement possibilities have come forward. Some of which have been adapted straight away, and some will be taken into account in an enhancement cycle of the framework. This chapter involves a listing of improvements and an enhanced version of the framework. Concluding the chapter on framework enhancement, the enhanced framework will be evaluated by comparing it with the sustainable development and EBM principles, as they were introduced in Part 0.

11.1 Strengths and improvements of the framework

First of all, the framework has been run successfully for the case study of a marina in Mauritius. It provided insight on how a marina interacts with the environment in a complete manner, i.e. considering all Ecosystem Services and all marina/marina use elements.

An important notion to mention is the ecosystem-based approach of the framework. The integration of an elaborate ecosystem assessment at an early stage is an addition to existing practices, and therefore has received more attention throughout the case study. Parallel analyses are also of critical importance and cannot be neglected or considered as briefly as they were considered in the case study. Along the same lines, the governing element of ecosystem-based coastal zone management is a key element in the framework. It is of key importance in order to reach the goal of a sustainable marina, with the marina being part of a sustainable coastal zone.

To following enhancements can be made, in order of the framework steps.

Table 21 - Framework enhancements

Framework location	Framework Enhancement	Notes
EBM outputs;	1 Eco-regions	Area of interest translated to eco-region.
	2 Ecosystem Services	Eco-region subdivided in areas of equal Ecosystem Services and features (rivers, bathymetry)
	3 Marine zoning	MPA, pressure zones, coastal uses.
Marina – Ecosystem interrelation matrix;	4 Simplification	A single relation between each ecosystem service and marina element (instead of 4), and 8 Marina (use) elements, 13 Ecosystem Services.
	5 Weighting	Each ecosystem service and marina element may be differently represented per marina/ecosystem.
	6 Additional information	Include the effect of sustainable practices, and include the extent to which ES are interesting for marinas.
Parallel analyses;	7 Legislative analysis	National strategies/vision on tourism, economy, coastal zone management etc.
Focal points – EBM;	8 Feedback loop	Focal points in marina – ecosystem assessment are useful for the continued EBM plan learning.
Stakeholders;	9 Stakeholder participation	The five types of stakeholder incorporation are given their specific place in the framework
Alternatives;	10 No development option	An important reference for any development is the ‘zero-state’ option, where no development takes place.

The framework enhancements are elaborated below, with numbers in parentheses referring to the numbers in Table 20. In the next section, Section 11.2, the enhanced framework is presented.

EBM Outputs

During the initiation phase, an area of interest is given from the initiating party. To fit in with coastal zone policy, this area needs to be translated to an eco-region (1), the scale that is used by an ecosystem-based coastal zone management plan. This way, an EBM coastal zone management plan can be operationalized, tracking all developments and status in that eco-region. At a higher level, the collection of eco-regions can be monitored, as they exchange/share services as well. To assess the eco-region for a marina development, the eco-region can be subdivided in areas that are similar in terms of the sets of Ecosystem Services, and features like bathymetry, river discharges, ecosystem pressure zones et cetera (2). In the case study, this has been illustrated in Figure 22 and Figure 23. By doing this, every location thinkable in the eco-region is captured, excluding the possibility that any potential locations are missed. Location selection in the ecosystem-based framework should be based on the various assessments, and should not be pre-chosen. The information to make the subdivision of areas and eco-regions is provided by the EBM coastal zone management plan. Also, the plan shares a marine zoning plan for the eco-region of interest, with designated marine protection areas, touristic areas, natural areas and areas reserved for certain development (3). Because the overarching EBM coastal zone management plan is responsible for the monitoring of cumulative impacts, safeguarding of long-term objectives and environmental, social and commercial targets, the information provided (1, 2 and 3) has to be given at the EBM level during the initiation phase.

Marina – Ecosystem interrelations tool

Simplification

In the analyses stage of the development phase, a couple of enhancements can be applied to the framework, most notably in the ecosystem assessment. Whilst executing the framework, it became clear that the marina – ecosystem interrelation tool would need to be simplified in order to increase clarity, workability and reduce the risk of too much detail at this stage of marina development (4). The tool can be used in cycles, in subsequent stages of marina design. At the stage where the tool has been used in this case study, sufficient detail was achieved to identify the focal points, and to inform the location evaluation process. The way it has been simplified is 1) by reducing the level of detail per interrelation, and 2) by reducing the amount of marina elements. Before, each interrelation was split up in two; the way the marina element would impact the ecosystem service, and second, the way the ecosystem service affected the marina element. This could be valuable

information, as the nature of the interrelation may be very different. To determine focal points and to base location evaluation on, this information is not necessary. The amount of marina elements has been reduced by grouping the elements more and avoiding double ratings in for example dredging and maintenance dredging.

Weighting system

Additionally, a weighting system has been implemented in the framework (5). Because every ecosystem provides more or less of specific Ecosystem Services, and because a marina element may be less or more pronounced in different settings (for example, deep or shallow water), the interrelations can be more or less meaningful. To clarify, the interrelation between dredging works and life cycle maintenance (habitat) is negative, as dredging can have destructive effects. However, for a very deep area, or an area that does not provide any habitat, this interrelation is still very negative, but not applicable to the setting. However, for a shallow coral area, for example, the negative effects are very much present.

Additional information

Besides the weighting of Ecosystem Services and marina elements, two more rows of information are included in the marina – ecosystem interrelation tool (6); a row that indicates how interesting certain Ecosystem Services are to a marina development and a row (or actually, column) that indicates the extent to which sustainable practices or measures can be applied to the different marina elements. For example, onshore activities can have a very negative effect, as is to be seen in the matrices from the case study, but can also very much be mitigated and controlled. Sustainable practices can cancel out the very negative scores it has for certain Ecosystem Services, and change it to a 'no relation' or less negative effect.

Parallel analyses

In other analyses, one important analysis that applies is an assessment of existing legislation, national strategy and vision. For the case study of Mauritius, these are very important elements for the marina development. The different strategies have been named, and taken into account, but a separate analysis at the analysis stage of the development phase would be a more logical place to deliver input for location selection and subsequent development processes. So, to enhance the framework an additional analyses, the legislative analysis, will be included in the framework (7).

From the marina – ecosystem interrelation tool, focal points have been derived, together with input for location selection and an understanding of the natural environment the marina may be developed in. To continue to develop the ecosystem-based coastal zone management plan, this information is very valuable. It increases the scientific base for coastal zone management, with

respect to the ecosystems at hand and with respect to how a marina interacts with those ecosystems. This feedback system is added to the framework (8).

Stakeholders

The stakeholder analysis has grouped all groups with an interest in marina development, and subsequently has assigned an approach method to every stakeholder to incorporate the respective stakeholder. There are five approaches possible, based on (Bryson, 2004); Inform, Consult, Involve, Collaborate and Empower. The different approaches apply at different stages of marina development. For example, all stakeholders need to be informed of upcoming plans making in an early stage. But actually involving, or collaborating, takes place at the analyses stage, or at the development of alternatives stage, or even both, continually. Empowerment of stakeholders, the top level of stakeholder involvement, takes place at a later stage, when design detailing is at hand. Please note, that stakeholders that are assigned an 'Empowerment' approach, will also be present at involvement and collaboration stages. Stakeholders that are just 'Informed' are not part of consultations or collaborations and are not empowered. In the enhanced framework, the respective stages at which the stakeholder incorporation approaches take place are indicated (9).

Alternatives

A last enhancement of the initial framework is the integration of the 'no development' option in the alternative selection process (10). This is an important reference to compare marina alternatives with. This enhancement came forward whilst comparing the initial framework with current practice in Mauritius, as elaborated in the ICZM strategy for the country.

The next section shows the enhanced framework, incorporating all points of improvement above. Naturally, additional executions of case studies and continued evaluation of the framework, will continue to improve the framework. This research study has included only one case study in a (sub)tropical environment.

11.2 Enhanced framework

In Figure 34, the enhanced framework is shown. It is based on the initial framework that was discussed in Part I of this report.

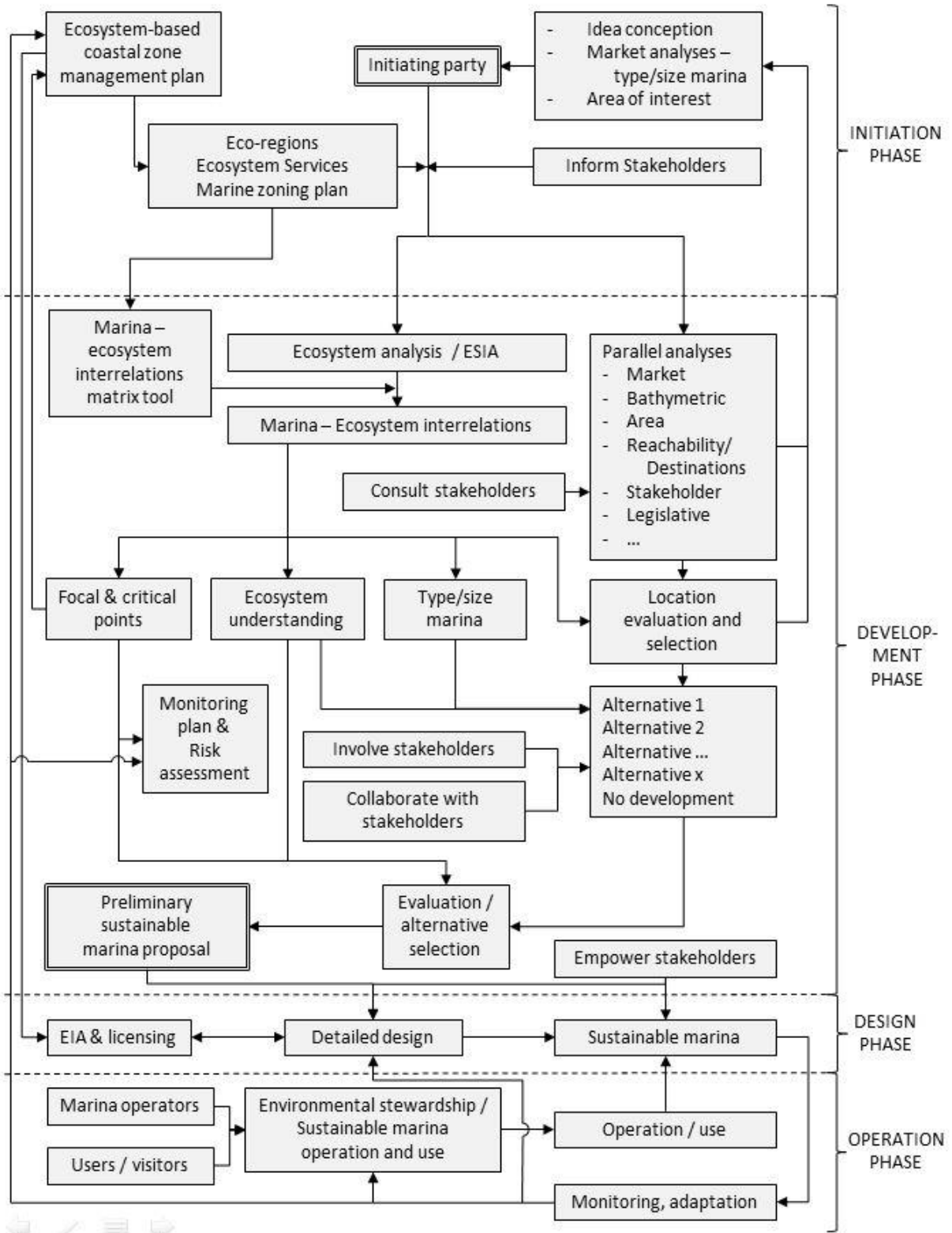


Figure 34 - Enhanced framework for sustainable marina development

11.3 Enhanced framework evaluation

This section discusses the effectiveness of the framework, with the experience from the case study in mind. In the previous two sections a series of improvements were made to enhance the framework. Most of the improvements helped make the framework more readily applicable; the link between the ecosystem-based coastal zone management plan and the marina development, for example, has been operationalized by the notion of eco-regions and subdivision by sets of Ecosystem Services. The stages at which stakeholders are incorporated in the framework are also solidifying the principle of stakeholder involvement, which is one of the sustainability- and EBM principles. Although the ecosystem assessment has been at the foreground of the framework, also social- and economic integration of a marina has been key in the location selection, as well as the alternative selection. Sustainable development requires integration of the marina across all sectors and disciplines. This element has been well represented in the case study. The simplifying round of the marina – ecosystem interrelations tool has also contributed to the workability and applicability of the framework.

An important notion about this case study, though, is the fact that details on topics were not known, and in some cases extrapolated from other areas. In reality, more detailed information on present Ecosystem Services, current land uses and bathymetry would be necessary input for the framework. Assumptions were made by extrapolation of areas where details were known, together with educated guesses based on the site visit and general knowledge on the subject. There were more assumptions throughout the case study, to be able to execute the framework. The largest are discussed below.

The largest assumption throughout the case study has been the presence of an ecosystem-based coastal zone management plan. In practice, this will happen more often. But, as introduced in Part I, a marina development can only be sustainable, if it is part of a larger zone, the eco-region, which on a whole, is sustainable. EBM overlooks development in the coastal zone, and safeguards sustainability principles like cumulative impacts, multiple (long-term) objectives and the adoption of an ecosystem perspective across the complete region. In Part II, it was seen that the ICZM framework of Mauritius does not suffice on these principles and a marina developed under ICZM guidance can therefore not be called sustainable.

Another large assumption has been the initiator's profile. In reality, there are endless possibilities to what an initiator's profile entails, what kind of marina is wished for, which type of customer base is being counted on and where in the world – in what kind of ecosystem – the marina should be. To make the framework generically applicable, more case studies should be done, in different contexts, and under different environmental, economic, social and political circumstances.

On the ecosystem interrelations, much is to be learned still. Understanding of marine ecosystems is not on a level where knowledge on terrestrial ecosystems is, leaving lots of knowledge to be learned from current and future research studies. The more is known about marine ecosystems, the better interrelations between ecosystem elements are understood and the better an assessment can be made on how a marina and marina use actually interacts with an ecosystem. More knowledge would allow more detail to be taken into account, with less uncertainty.

Uncertainty is a large factor in current ecosystem-based developments. It is the reason that one of the principles of ecosystem-based approaches is the principle of embracing change, learning and adapting. Continued learning, adaptive development and extensive monitoring are key to success in ecosystem-based developments and, ultimately, in achieving sustainability. In the framework, this has been represented by 1) a mid-development process of creating a monitoring & risk assessment plan, based on the focal and critical points found in the ecosystem assessment, and 2) actual monitoring/adaptation once the marina is in place, with a feedback loop to the detailed design stage, the operation and use stage and the ecosystem-based coastal zone management plan.

Concluding the framework is a preliminary proposal for a sustainable marina. A grand picture is given on how the marina should be designed like, and how this preliminary proposal is integrated in its environment. Detailed designing has to determine the exact configuration of docks, boats, paved areas, building placements et cetera. It is of great importance that the ecosystem understanding is brought to this stage of marina development as well. Focal points obtained from the ecosystem assessment are guiding important decisions on the marine structure and construction thereof. At this stage, additional guidelines and frameworks are applicable and can be used to the marina's advantage by supplying eco-friendly measures to control onshore activities, to use the right materials and to implement structures that provide opportunities for the ecosystem to develop.

Part IV. Conclusions & Recommendations

The final part of this report concludes the research with a reflection on achieved results. Chapter 0 gives the main conclusions and the substantiation of that conclusion. Chapter 0 also reflects on the conclusions that are made with respect to the case of Mauritius, supporting the framework study.

Chapter 13 ultimately, provides recommendations for additional research.

12. Conclusion: Ecosystem-based management principles translated to marina development practice

12.1 Introduction

The need to perform the research study was given by an inadequate set of guidelines for marina development; firstly, there has been determined to be a lack of guidelines for the initial stages of marina development. Existing guidelines mostly refer to the design stage, where a marina concept can be developed in detail. Important decisions like location selection and the marina's place in the natural environment are not guided by any guideline. Secondly, no regard is given to how a marina could be sustainable, or how the marina relates to the rest of the coastal zone.

The research study has resulted in a framework for sustainable marina development, focussing on the initial stages of marina development. The framework is therefore new in the field. Another new aspect that has been realized by the framework is the high regard that has been given to the sustainable development principles in marina development. The framework incorporated an ecosystem-based approach and has provided means to evaluate the interaction between the marina and its environment. In practice, it appears difficult to translate theory and concepts of sustainable development to practical decision-making. The marina – ecosystem interrelations tool that has been developed within the framework does just that. The framework pioneers the field of sustainable marina development.

The tool represents a way to evaluate the complete marina versus a complete representation of the ecosystem, represented by the Ecosystem Services. Due to the complete overview of interrelations between ecosystem services and marina elements, the critical interactions and potentially positive interactions can be identified, together with an invaluable insight on the marina's relation with the natural environment.

The high regard that has been given to sustainable development principles in marina development is not only new, it is also very much needed. This does not only apply to marinas, but to all coastal developments. Its place in the coastal environment and integration in society is of paramount importance to come to sustainable development. The framework, and highlighting the marina – ecosystem interrelations tool, is concluded to be of critical importance for successful sustainable marina development. It showed to effectively guide important decisions throughout the framework.

Developing the framework has started with achieving an understanding of sustainable development, marinas and the subsequent sustainable marina development. An important finding of the report has been that a marina cannot be called sustainable by itself. A sustainable marina is a marina that is an integral part of a coastal zone, which is managed for sustainability based on the ecosystem. The

framework produced in this research study successfully came to an ecosystem-based marina development for the island of Mauritius, and is generically applicable for any type of marina and any ecosystem configuration.

12.2 Conclusions

The main conclusion is as follows. To achieve a sustainable marina, a marina development requires to be guided by an ecosystem-based coastal zone management plan standing at the basis of a framework for the initial stages of marina development, assessing the marina's integration into social, ecological and economic context.

The strength of the framework is the consideration of multiple values in marina development; it considers the marina development as a part of the environment, taking into account all values the marina influences (ecological, societal and economic values).

Substantiating the above conclusion, the following sub-conclusions have been drawn throughout the research study;

- Initial marina development stages, including location selection and integration of a marina in its environment are not currently guided by guidelines, nor are they aimed at sustainable development,
- Subsequent marina development stages, including detailed designing and operations management are guided well by existing guidelines and initiatives, and name sustainability as a goal. There is room for improvement though,
- A marina has a good opportunity to fulfil an important element for ecosystem-based management (EBM); to provide a social platform, where local societies, marina management, marina users, scientists and volunteers can share insights and experiences on the shared environment,
- A sustainable marina is a marina that is an integral part of a coastal zone that is managed for sustainable development. Sustainable coastal zone development requires an ecosystem-based management approach,
- The tool provided in the framework, the marina – ecosystem interrelations matrix, provides adequate insight to improve marina development. It delivers critical information on location selection and alternatives selection,
- The tool and the framework are applicable for any marina in any ecosystem,
- However, the ecosystem assessment can be improved by additional knowledge on exact interrelations between marina elements and ecosystem services (see Recommendations).

For Mauritius, several important conclusions were drawn, supporting the findings on the framework;

- Current marina development practice does not succeed in Mauritius. The reason for this is the inadequate way of approaching marina development. Marina development proposals have been traditional, focussing on the functional value only. To succeed in Mauritius, the marina development has to take into account multiple values like its integration in nature, in society, in national strategy and socio-economic characteristics,
- Current Mauritian coastal zone management (ICZM) is well under way to monitor current developments and to deal with current problems like pollution and coastal erosion. However, it is not ecosystem-based, coming short on the integration of current developments in nature,
- The framework developed in this report has successfully been applied to the case of Mauritius, adopting an ecosystem-based approach to marina development,
- The framework delivered a location for marina development, that aligns with the many environmental concerns well. The location for marina development is suggested to be Petite Rivière Noire. For this case study, only the South West region was considered.
By applying the same ecosystem-based approach to alternative selection, the framework delivered a conceptual marina design for Petite Rivière Noire,
- The conceptual marina development successfully integrated nature, socio-economics and national strategies.

The case study has shown the workability of the framework, as well as the added value of the framework, by offering guidance in the creation of a conceptual sustainable marina development.

13. Recommendations: Sustainable marina development research

It is recommended to research the integration of this framework in the total marina development cycle, i.e. how it relates to subsequent stages of marina development, like design detailing, licensing and operations. Also, the framework itself can be developed by performing additional case studies; this would test the framework for different contexts and may lead to more enhancements like Chapter 11 of this research study has presented. For example, the enhancements have improved the integration of stakeholder approaches into the framework. Also, the workability of the marina – ecosystem interrelations has improved, by reducing complexity and introducing a ‘weighting’ system for the different interactions.

The marina – ecosystem assessment, can also become more valuable and precise when more information is available on the interrelations considered. To be precise, the interactions between the different marina (use) elements and the ecosystem services can be studied. An example would be the effect of flow limitation on the ecosystem’s ability to provide water quality improvement, or the effect of habitat enhancements within a marina basin on the ecosystem.

Additional research can also be done on the coastal zone management level, on the ecosystem-based management approach. The operationalization of the management approach is still a challenge around the world, although its merit is widely acknowledged. In a comparison between coastal zone management approaches, the impression was given that Integrated Coastal Zone Management (ICZM) may be easier to implement in existing organizational structures than EBM is. Additional research could investigate this issue and propose measures to evolve the EBM approach, so that it becomes well applicable in existing governance structures.

Bibliography

- Arkema, K. K., Abramson, S. C., & Dewsbury, B. M. (2006). Marine ecosystem-based management: from characterization to implementation. *Frontiers in Ecology and the Environment*, 4(10), 525-532.
- ASCLME. (2012a). *National Marine Ecosystem Diagnostic Analysis. Mauritius*. Retrieved from Contribution to the Agulhas and Somali Current large marine Ecosystems Project (supported by UNDP with GEF grant financing)
- ASCLME. (2012b). *Transboundary Diagnostic Analysis of the Large Marine Ecosystems of the western Indian Ocean*. Retrieved from South Africa
- Baars, W., Harmsen, H., Kramer, R., Sesink, L., & van Zundert, J. (2015). *Handboek Projectmanagement versie 1.2*. <https://www.projectmanagement-training.nl/artikelen-en-tools/handboek-projectmanagement/>.
- Baird. (2003). *Study on Coastal Erosion in Mauritius. Final Technical Report Volume 1*. Retrieved from Oakville, Canada
- Balmford, A., Naidoo, R., & Manica, A. (2009). A Global Perspective on Trends in Nature-Based Tourism. Retrieved from <http://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1000144>
- Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C., & Silliman, B. R. (2011). The value of estuarine and coastal Ecosystem Services. *Ecological Monographs*, 81(2), 169-193.
- Barbier, E. B., Koch, E. W., Silliman, B. R., Hacker, S. D., Wolansky, E., Primavera, J., . . . Reed, D. J. (2008). Coastal Ecosystem-Based Management with Nonlinear Ecological Functions and Values. *Science*, 319, 321-330.
- Beaumont, N. J., Austen, M. C., Atkins, J. P., Burdon, D., & S., D. (2007). Identification, definition and quantification of goods and services provided by marine biodiversity: implications for the ecosystem approach. *Marine pollution bulletin*, 54, 253 - 265.
- Beger, M., Harborne, A. R., Dacles, T. P., Solandt, J.-L., & Ledesma, G. (2005). A Framework of Lessons Learned from Community-Based Marine Reserves and Its Effectiveness in Guiding a New Coastal Management Initiative in the Philippines. *Environmental Management*, 34(6), 786-801.
- BOI. (2013). Investment Opportunities: Marina Development. In M. Board of Investment (Ed.). Port Louis, Mauritius.
- Bryson, J. M. (2004). What to do when stakeholders matter. Stakeholder identification and analysis techniques. *Public Management Review*, 6(1), 21-53.
- Cicin-Sain, B. (1993). Sustainable Development and Integrated Coastal Management. *Ocean & Coastal Management*, 21, 11-43.
- Cicin-Sain, B., Knecht, R. W., Dosoo, J., & Fisk, G. W. (1998). *Integrated coastal and ocean management: concepts and practices*. Washington DC: Island Press.
- Clark, J. R. (1992). *Integrated management of coastal zones*. Retrieved from FAO Fisheries technical paper No. 327
- Curtin, R., & Prellezo, R. (2010). Understanding marine ecosystem based management: A literature review. *Marine Policy*, 34, 821-830.
- de Groot, R., Alkemade, R., Braat, L., Hein, L., & Willemsen, L. (2010). Challenges in integrating the concept of Ecosystem Services and values in landscape planning, management and decision making. *Ecological Complexity*, 7, 260-272.
- de Vriend, H. J., van Koningsveld, M., & Aarninkhof, S. G. J. (2015). Sustainable hydraulic engineering through building with nature. *Journal of Hydro-environment Research* 9, 159-171.
- Deltares, Rijkswaterstaat, & Ecoshape. (2013). *Eco-engineering in the Netherlands. Soft interventions with a solid impact*. Retrieved from <http://kennisonline.deltares.nl/product/30490>.
- Epsilon Associates Inc. (2001). *Massachusetts Clean Marina Guide - Strategies to Reduce Environmental Impacts*. Retrieved from Boston: www.state.ma.us/czm/

- Fontaine, M. W., & Dunn, M. P. (2008). *Overview of the Recreational Boating Industry's Aquatic Stewardship through Technology, Innovation and Education*. Retrieved from National Marine Manufacturers Association (NMMA)
- Forst, M. F. (2009). The convergence of Integrated Coastal Zone Management and the ecosystems approach. *Ocean & Coastal Management*, 52, 294-306.
- Glasby, T. M. (1997). Analysing data from post-impact studies using asymmetrical analyses of variance: A case study of epibiota on marinas. *Austral Ecology*, 22(4), 448-459.
- Government of Mauritius. (2013). *Maurice Ile Durable Policy, Strategy and Action Plan*. Retrieved from Port Louis, Mauritius
- Granek, E. F., Polasky, S., & V. Kappel, C. (2009). Ecosystem Services as a Common Language for Coastal Ecosystem-Based Management. *Conservation Biology*, Volume 24, 207-216.
- Haines-Young, R., & Potschin, M. (2011a). *Common International Classification of Ecosystem Services (CICES)*. 2011 Update. Nottingham: Report to the European Environmental Agency.
- Haines-Young, R., & Potschin, M. (2011b). *Integrated Coastal Zone Management and the Ecosystem Approach*. . Deliverable D2.1 Working Paper No.7. PEGASO Project, Centre for Environmental Management.
- Halpern, B. S., Walbridge, S., Selkoe, K. A., V. Kappel, C., Micheli, F., D'Agrosa, C., . . . Ebert, C. (2008). A Global map of Human Impact on Marine Ecosystems. *Science*, 319(5865), 948-952.
- Hume, J. P., & Cheke, A. S. (2008). *Lost Land of the Dodo: The Ecological History of Mauritius, Reunion, and Rodrigues*. Yale: Yale University Press.
- Katsanevakis, S., Stelzenmüller, V., South, A., Sorensen, T. K., & Jones, P. J. S. (2011). Ecosystem-based marine spatial management: Review of concepts, policies, tools and critical issues. *Elsevier*, 54, 807-820.
- La Balise. (2016). La Balise Marina official website. Retrieved from <http://www.labalise marina.com/en>
- Landell Mills. (2010). *Development of an Integrated Coastal Zone Management Framework (ICZM) for the Republic of Mauritius*. Retrieved from: Ministry of Environment, Mauritius.
- Levin, P. S., Fogarty, M. J., Murawsky, S., & Fluharty, D. (2009). Integrated Ecosystem Assessments: Developing the Scientific Basis for Ecosystem-Based Management of the Ocean. *PLoS Biology*, 7(1), 23-28.
- Levin, S. A., & Lubchenco, J. (2008). Resilience, Robustness, and Marine Ecosystem-based Management. *BioScience*, 58(1), 27-32.
- Lipton, D. (2004). The Value of Improved Water Quality to Chesapeake Bay Boaters. *Marine Resource Economics*, 19, 265-270.
- Liquete, C., Piroddi, C., Drakou, E. G., Gurney, L., Katsanevakis, S., Charef, A., & Egoh, B. (2013). Current Status and Future Prospects for the Assessment of Marine and Coastal Ecosystem Services: A Systematic Review. *PLoS ONE*, 8(8). doi:10.1371/journal.pone.0067737
- Long, R. D., Charles, A., & Stephenson, R. L. (2015). Key principles of marine ecosystem-based management. *Marine Policy*, 57, 53-60.
- Matlock, M. D., & Morgan, R. A. (2011). *Ecological Engineering Design: Restoring and Conserving Ecosystem Services* (pp. 353).
- Mauritius Meteorological Services. (2008). *Report on tidal analysis & prediction Mauritius*. Retrieved from Mauritius: MMS.
- McAllister, T. L., Overton, M. F., & Brill, E. D. (1996). Cumulative Impact of Marinas on Estuarine Water Quality. *Environmental Management*, 20(3), 385-396.
- McLeod, K. L., Lubchenco, J., Palumbi, S. R., & Rosenberg, A. A. (2005). Scientific Consensus Statement on Marine Ecosystem-Based Management.: Signed by 221 academic scientists and policy experts with relevant expertise and published by the Communication Partnership for Science and the Sea at http://www.compassonline.org/science/EBM_CMSP/EBMconsensus.
- McPherson, S. B., van Schagen, S., Besteiro, S., Leonard, G. H., & Williamson, P. T. (2014). Good Mate Brochure, Recreational Boating & Marina Manual, Charting a Course to Clean Water. In O. Conservancy (Ed.).

- MEAM. (2011). Making the Most of Stakeholder Involvement in EBM: Practitioners and Researchers Share their Insights. Retrieved from <https://meam.openchannels.org/news/meam/making-most-stakeholder-involvement-ebm-practitioners-and-researchers-share-their-insights>.
- Millenium Ecosystem Assessment. (2005). *Ecosystems and Human Well-being: A Framework for Assessment*. Retrieved from Island Press, Washington DC
- Ministry of Environment. (2016). EIA Reports. Retrieved from <http://environment.govmu.org/English/eia/Pages/EIA-Reports.aspx>
- Ministry of Environment & Sustainable Development. (2011). *Mauritius Environment Outlook Report*. Retrieved from Ministry of Environment, Mauritius.
- Ministry of Environment & Sustainable Development. (2013a). *Guideline on the content of an Environment Impact Assessment Report for Construction of Marinas*. Mauritius.
- Ministry of Environment & Sustainable Development. (2013b). *Maurice Ile Durable, Policy, Strategy and Action Plan*. Retrieved from Mott MacDonald, Leeds
- Ministry of Housing and Lands. (2004). *Planning and Policy Guidance, Design Sheet Marina Development*. Mauritius.
- Moreno, J., Palomo, I., Escalera, J., Martín-López, B., & Montes, C. (2013). Incorporating Ecosystem Services into ecosystem-based management to deal with complexity: a participative mental model approach. *Landscape Ecology*, 29, 1407-1421.
- Mulder, K., Ferrer, D., & van Lente, H. (Eds.). (2011). *What is Sustainable Technology? : Greenleaf Publishing Ltd*.
- Neil Ross Consultants. (1996). *Clear Marinas - Clear Value - Environmental and Business Success Stories*. Retrieved from Washington, DC: US EPA
- NOAA. (2016). Merged Land Ocean Global Surface Temperature Analysis (NOAAGlobalTemp). Retrieved from <https://www.ncdc.noaa.gov/data-access/marineocean-data/noaa-global-surface-temperature-noaaglobaltemp>
- PIANC. (1979). *Standards for the construction, equipment and operation of yacht harbours and marinas with special reference to the environment*. Retrieved from <http://www.pianc.org>.
- PIANC WG12. (2002). *Recreational Navigation and Nature*. Retrieved from <http://www.pianc.org>.
- PIANC WG98. (2008). *Protecting Water Quality in Marinas*. Retrieved from <http://www.pianc.org>.
- PIANC WG149. (2016). *Guidelines for Marina Design*. Retrieved from <http://www.pianc.org>
- Pomeros, R. C., M.B. (1997). Community-based coastal resource management in the Philippines: a review of programs and projects, 1984-1996. *Marine Policy*, 21, 445-464.
- Pomeroy, A., Lowe, R., Symonds, G., Van Dongeren, A., & Moore, C. (2012). The dynamics of infragravity wave transformation over a fringing reef. *Journal of Geophysical Research*, 117(C11022), 17. doi:10.1029/2012JC008310
- Prime Minister's Office. (2013). *The Ocean Economy. A roadmap for Mauritius*. Retrieved from Port Louis, Mauritius
- Ruckelshaus, M., Klinger, T., Knowlton, N., & DeMaster, D. P. (2008). Marine Ecosystem-based Management in Practice: Scientific and Governance Challenges. *BioScience*, 58(1), 53-63.
- Scheffer, M., Carpenter, S., Foley, J. A., Folke, C., & Walker, B. (2001). Catastrophic shifts in ecosystems. *Nature*, 413, 591-596.
- Sorensen, J. (1997). National and international efforts at integrated coastal management: Definitions, achievements, and lessons. *Coastal Management*, 25, 3-41.
- Standards Australia International. (2001). AS 3962-2001 Guidelines for design of marinas: Standards Australia International Ltd.
- Tallis, H., Levin, P. S., Ruckelshaus, M., Lester, S. E., McLeod, K. L., Fluharty, D., & Halpern, B. S. (2009). The many faces of ecosystem-based management: Making the process work today in real places. *Marine Policy*, 34(1), 340 - 348.
- TEEB. (2010). *The Economics of Ecosystems and Biodiversity: ecological and economic foundation*. London and Washington: Earthscan.
- Thia-Eng, C. (1993). Essential Elements of Integrated Coastal Zone Management. *Ocean & Coastal Management*, 21(1), 81-108.

- UN Sustainable Development. (2016). United Nations Sustainable Development Goals. Retrieved from <http://www.un.org/sustainabledevelopment/sustainable-development-goals/>
- UNEP. (1995). Global biodiversity assessment.
- UNEP, & MARE. (2011). Taking Steps toward Marine and Coastal Ecosystem-based Management *An Introductory Guide*.
- van Eeten, M. J. G., & Roe, E. (2002). *Ecology, Engineering, and Management: reconciling ecosystem rehabilitation and service reliability*. New York: Oxford University Press, Inc.
- Warnken, J., & Buckley, R. (2000). Monitoring Diffuse Impacts: Australian Tourism Developments. *Environmental Management*, 25(4), 453-461. doi:10.1007/s002679910036
- Waterman, R. (2010). *Integrated Coastal Policy via Building with Nature*.
- World Wildlife Fund. (2016, 2016). WWF Global - What is an ecoregion? Retrieved from http://wwf.panda.org/about_our_earth/ecoregions/about/what_is_an_ecoregion/
- WTTC. (2015). *Travel & Tourism - Economic impact 2015 Seychelles*. Retrieved from London, United Kingdom.

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Appendix A. Marina elements

In Chapter 2, Section 2.2, a marina development has been split up in a set of marina elements. Partially these elements are part of the physical marina, like structure and dredging activities, where the second half of elements considers the marina use elements.

The collection of elements broadly captures all elements that interact with the natural environment. As such, these elements will be used in the ecosystem assessment (Section 5.2) as a representative set of elements of a marina development.

In Figure 35 an elaboration of each marina element is given, clarifying the meaning and encompassment of each element.

	Marina element	Description of marina element
Marina	Structural elements	Hard, fixed structures like breakwaters, fixed jetties and quays. Typical characteristics are their protective qualities, flow blocking effects, high costs and opportunities to habitat creation by introducing rough area, with calm waters. They rest on the sea floor, and require more construction effort than most other structures.
	Floating elements	Floating elements are floating docks, or floating breakwaters, structures that are fixed in place, but do not block any water flow or disturb the sea bed area. They provide shade to the water body and create extra habitat opportunities. Floating elements are not as good as hard structural elements in resisting wave action, or at providing shelter.
	(Maintenance) dredging	(Maintenance) dredging comprises initial capital dredging operations as well as periodic maintenance dredging. Dredging operations impact the water body by stirring up sediment and the sea bed by lowering the bed level and destruction of habitat
	Bottom structures	Bottom structures are often used for anchoring purposes. Docks, marks or boats can be anchored. A bottom structure could be a pile, or simply a concrete block with a chain or rope attached to it. Although the structure provides some shelter for marine life, and extra habitat is created, the swinging chains/ropes are known to negatively impact the surrounding sea bed.
	Construction & maintenance	Construction & maintenance involves all operations to create the marina structure, and to keep the physical marina in shape throughout its life time. Relocating landfill, occupation of sea beds or land area, material use and equipment use relate to the environment in a mostly negative way.
Marina use	Boat presence	Presence of boats considers the berthed boats as well as the moving boats, motorized and not motorized. Moving boats deliver disturbance to marine life, and through their wastes, oil and fuel spills, nutrients they may be polluting the water column and affect marine life. The mix of boats present in and around the marina is an important factor.
	Onshore activities	Onshore activities comprises of social events, but also general marina use from boaters and marina operators. Repair works, paved areas, sewage systems and storm run-off are of impact to the coastal zone.
	Social- / community places	Social- and community places offer opportunity for educational purposes, promoting environmental stewardship, social coherence, a central place for local societies to recreate, commune and do business or yacht club activities. A communal area provides a good platform for NGOs and other parties to base their research programme and initiatives from.
	Marine activities	Boating, snorkelling, scuba diving, fishing, whale- / dolphinwatching, water skiing and other activities put stress on the environment. Disturbance of the water column, pollution, trampling, animal harassing are example of marine activities that impact the ecosystem

Figure 35 - Marina and marina use elements

Appendix B. Marine and coastal Ecosystem Services

Below, the results of the research study performed by Liqueete *et al.* are presented. The results are shortly discussed below. The shaded set of ES in Figure 36 is used throughout this research study.

	This research study, based on (Liqueete <i>et al.</i> , 2013)	Millenium Ecosystem Assessment (2005)	Beaumont	TEEB (2010)	CICES (2011)	
Provisioning	Food provision	Food	Food provision	Food	Terrestrial plant and animal	
					Freshwater plant and animal	
					Marine plant and animal	
	Water storage and provision	Fresh water	N/A	Water	Potable water	
					Water flow regulation	
					Water quality regulation	
	Biotic materials and biofuels	Ornamental resources	Raw materials	Ornamental resources	Biotic materials	
		Genetic resources		Genetic resources		
		Biochemicals		Medicinal resources		
		Fiber		Raw materials		Renewable biofuels
Regulating and maintenance	Water purification	Water purification and waste treatment	Bioremediation of waste	Waste treatment	Bioremediation	
		Nutrient cycling ¹	Nutrient cycling ¹		Water quality regulation	
	Air quality regulation	Air quality regulation	Gas and climate regulation	Air quality regulation	Dilution and sequestration of wastes	Mass flow regulation
	Water regulation	Regulation of water flows	Water flow regulation			
	Erosion regulation	Erosion prevention	Air flow regulation			
	Climate regulation	Climate regulation	Gas and climate regulation	Climate regulation	Atmospheric regulation	
	Weather regulation		N/A			
	Ocean nourishment	Soil formation ¹	Nutrient cycling ¹	Maintenance of soil fertility	Pedogenesis and soil quality regulation	
		Nutrient cycling ¹				
	Life cycle maintenance	Pollination	Biologically mediated habitat ¹	Maintenance of life cycles of migratory species ¹	Life cycle maintenance and habitat protection	Gene pool protection
				Maintenance of genetic diversity ¹		
				Pollination		
Biological regulation	Pest regulation	N/A	Biological control	Pest and disease control		
	Disease regulation					
Cultural	Symbolic and aesthetic values	Spiritual and religious values	Cultural heritage and identity	Spiritual experience	Spiritual	
		Cultural heritage values				
		Cultural diversity				
		Sense of place				
	Aesthetic values	Feel good or warm glow	Aesthetic information	Aesthetic, heritage		
	Recreation and tourism	Recreation and eco-tourism	Leisure and recreation	Opportunities for recreation and tourism	Recreation and community values	
		Social relations				
	Cognitive effects	Inspiration	Cognitive effects	Inspiration for culture, art and design	Information and knowledge	
Knowledge systems		Information for cognitive development				
Educational values						

Foot note: 1: supporting services

Figure 36 - Marine and coastal Ecosystem Services, adopted from (Liqueete *et al.*, 2013)

In Figure 37, the individual services are elaborated and defined.

	Ecosystem service	Description of ecosystem service
Provisioning	Food provision	a. Fishing activities (including shellfishing) industrial or artisanal (either commercial or subsistence fishing). In general, fisheries are reported as total landings or catch per unit effort and, sometimes, corresponding jobs. b. Aquaculture is the farming of aquatic organisms, including fish, crustaceans, mollusks, seaweeds and algae.
	Water storage and provision	a. Water abstraction in marine and coastal environments is mostly associated to coastal lakes, deltaic aquifers or desalination plants. b. Marine water may also be used for industrial cooling processes or coastal aquaculture in ponds and raceways.
	Biotic materials and biofuels	a. This includes medicinal (e.g. drugs, cosmetics), ornamental (e.g. corals, shells) and other commercial or industrial resources (e.g. whale oil, fishmeal, seal leather, algal or plant fertilizers). b. Biomass to produce energy can have a solid form (like wood from mangroves), liquid (like fuels extracted from algal lipids or whale oil) or biogas (from decomposing material).
Regulating and maintenance services	Water purification	Treatment of human wastes (e.g. nitrogen retention); dilution; sedimentation, trapping or sequestration (e.g. of pesticide residues or industrial pollution); bioremediation (e.g. bioaugmentation after marine oil spills); oxygenation of "dead zones"; filtration and absorption; remineralisation; decomposition.
	Air quality regulation	Vegetation (e.g. in mangroves), soil (e.g. in wetlands) and water bodies (e.g. open ocean), due to their physical structure and microbiological composition, absorb air pollutants like particulate matter, ozone or sulphur dioxide.
	Coastal protection	Natural defense of the coastal zone against inundation and erosion from waves, storms or sea level rise. Biogenic and geologic structures that form the coastal habitats can disrupt the water movement and, thus, stabilize sediments or create buffering protective zones.
	Climate regulation	The ocean acts as a sink (and only a very marginal source) for greenhouse and climate active gases. Inorganic carbon is dissolved into the seawater, organic carbon is formed through primary producers, a percentage of which is stored, and a percentage of which is sequestered.
	Weather regulation	For example, the influence of coastal vegetation and wetlands on air moisture and, eventually, on the saturation point and the formation of clouds.
	Ocean nourishment	Natural cycling processes leading to the availability of nutrients in the seawater for the production of organic matter. Pedogenesis could be observed at the margin of certain wetlands and mangroves, depending on hydrodynamic conditions.
	Life cycle maintenance	The maintenance of key habitats that act as nurseries, spawning areas or migratory routes (e.g. seagrasses, coastal wetlands, coral reefs, mangroves). These habitats and the connectivity among them are crucial for the successful life cycle of species. This also includes pollination (e.g. mangrove pollination), and seed and gamete dispersal by organisms. This service guarantees the maintenance of genetic diversity or gene pool protection.
	Biological regulation	Control of fish pathogens especially in aquaculture installations; role of cleaner fishes in coral reefs; biological control on the spread of vector borne human diseases; control of potentially invasive species.
Cultural services	Symbolic and aesthetic values	Coastal communities have always shown strong bonds to the sea due to the local identity. Natural and cultural sites linked to traditions and religion are numerous in the coastal zone. Both coastal and inland societies value the existence and beauty of charismatic habitats and species such as coral reefs or marine mammals.
	Recreation and tourism	The appeal of marine ecosystems is usually linked to wilderness, sports, or iconic landscapes and species. It can be related to coastal activities (e.g. bathing, sunbathing, snorkeling, scuba diving) and offshore activities (e.g. sailing, recreational fishing, whale watching).
	Cognitive effects	Inspiration for arts and applications (e.g. architecture designs inspired in marine shells, medical applications replicating marine organic compounds). Material for research and education (e.g. discoveries of new deep sea species). Information and awareness (e.g. respect for nature through the observation of marine wild life).

Figure 37 - Marine and coastal Ecosystem Services classification by Lique et al., 2013

The research study of Lique *et al.* entailed the collection and analysis of four frequently encountered representations of the concept of Ecosystem Services. The most well-known classification of Ecosystem Services has been given by the Millennium Ecosystem Assessment in 2005. Other classifications are done by Beaumont, but slightly less elaborately, TEEB, an organization that incorporates Ecosystem Services in the valuation of ecosystems and by CICES, the Common International Classification of Ecosystem Services. The latter aims for standardisation in the way we describe Ecosystem Services.

All classifications are very similar to each other, presenting only small differences. As these classification apply to ecosystems in general (marine, terrestrial et cetera), Liqueete has adapted the classification to specifically adjust it to marine and coastal ecosystems (Liqueete *et al.*, 2013).

In this classification, the supporting services like nutrient cycling, soil formation and provisioning of habitat are integrated in the other services (see footnote in Figure 36). As Ecosystem Services depend on these supporting services, applying this integration prevents double-evaluation.

This classification is appropriate to use in this research study as for the ecosystem assessment the marine and coastal ecosystem is considered. Also, by integrating the supplying services into the other services groups, these are more practical to consider in relation to a marina development.