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Assessing vulnerability to coastal hazards case study: Gozo

Jonathan Portelli
James Madison University

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Assessing Vulnerability to Coastal Hazards
Case Study: Gozo

Jonathan Portelli

Master of Science in Sustainable Environmental Resource Management
University of Malta
2010
Assessing Vulnerability to Coastal Hazards
Case Study: Gozo

A dissertation presented in part fulfilment of the requirements for the
Degree of Master of Science in Sustainable Environmental Resource
Management

Jonathan Portelli
November 2010
Supervisor: Dr. Louis. F. Cassar
Co-Supervisors: Dr. Elisabeth Conrad; Dr. Bob Kolvoord

University of Malta – James Madison University
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ABSTRACT

Assessing Vulnerability to Coastal Hazards – Case study: Gozo

Jonathan Portelli

All coastal areas around the globe are vulnerable to a series of potential hazards at different degrees depending on location, altitude above sea level, geomorphological features and socio-economic factors, including demography, human settlement and infrastructural development. Since the 1990s a major effort in developing appropriate methodologies and guidelines to assess coastal vulnerability has been made.

Of significant importance, the coast of Gozo embraces both natural and anthropogenic features that occupy a relatively small area. Consequently, coastal vulnerability by multiple coastal hazards is a fact due to the topography of the island, overpopulation in some coastal locations, and intensive coastal development and accompanying infrastructure. In the light of these threats the main aim of this research is to investigate coastal vulnerability relating to five coastal hazards, namely, tsunami, storm surge, sea level rise, flooding and landslide, while at the same time identifying areas likely to be at high risk.

Varied data collection techniques are used to gather data from several stakeholders while visual analysis techniques are utilised to geographically map coastal risk zones. Research findings show that low lying coastlines appear to be at high risk and are vulnerable to multiple hazards. In addition, the local population in Gozo appears to have scant knowledge on the subject along with a lack of awareness and preparedness. In turn, several recommendations, which aim at creating a sustainable approach towards coastal vulnerability and hazards, are proposed. These recommendations aim at helping decision makers towards a better risk management approach for Gozo.

Dr. Louis. F. Cassar (Supervisor)                            MSc. SERM / MS. ISAT
Dr. Elisabeth Conrad (Co-Supervisor)                       November, 2010
Dr. Bob Kolvoord (Co-Supervisor)

KEY WORDS: COASTAL VULNERABILITY - NATURAL HAZARDS - AWARENESS AND PREPAREDNESS - COASTAL RISK MANAGEMENT.
DECLARATION OF AUTHENTICITY

I confirm that this dissertation is all my work and does not include any work competed by anyone other than myself, except where due reference has been made.

_________________________________
Jonathan Portelli
DEDICATION

To my grandfather
Charles. P. Camilleri

For his support throughout my academic years...
ACKNOWLEDGEMENTS

I should like to start by extending my sincere gratitude to my UoM supervisor and co-supervisor Dr. Louis. F. Cassar and Dr. Elisabeth Conrad, and also to JMU co-supervisor Dr. Bob Kolvoord for their constant assistance, patience, and useful guidance. I personally want to thank them for their help, interest and support.

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Generally, my sincere thanks are due to the people of Gozo, who in one way or another, contributed towards the successful outcome of this work, especially when surveys were carried out.

Last but certainly not less, I am greatly indebted to my parents Lydia and Anthony Portelli, my grandfather Charles. P. Camilleri and to my fiancée Charmaine Bugeja for their remarkable continual support and encouragement. Finally, I would like to thank all those who in different ways helped me during both the research and writing of this dissertation but who are not mentioned above.
## TABLE OF CONTENTS

Abstract iii  
Declaration of Authenticity iv  
Dedication v  
Acknowledgements vi  
Contents vii  
List of Figures xii  
Lists of Plates xiii  
List of Tables xiv

### Chapter 1  INTRODUCTION

1.1 Chapter Outline 1  
1.2 Topic Research 2  
1.3 Aims and Objectives 4  
1.4 Case study Area 5  
1.5 Dissertation Structure 7

### Chapter 2  LITERATURE REVIEW

2.1 Chapter Outline 8  
2.2 Coastal Areas: values and importance 9  
2.2.1 Importance of Coastal Areas to Mankind 10  
   2.2.1.1 Tourism and recreation 11  
   2.2.1.2 Coastal infrastructure 12  
   2.2.1.3 Coastal biodiversity 12  
2.3 Causes and Dynamics of Coastal Hazards 13  
   2.3.1 Risks of Coastal Hazards 15
2.3.1.1 Storm surge 16
2.3.1.2 Coastal flooding 16
2.3.1.3 Tsunami 17
2.3.1.4 Landslide 17
2.3.1.5 Sea level rise 18

2.4 Coastal Vulnerability: the need to know 19
2.4.1 The Importance of Coastal Vulnerability 20
   2.4.1.1 Vulnerability hotspots 22
   2.4.1.2 Coastal vulnerability indicators 23
   2.4.1.3 Global, regional and local scale vulnerability assessment 24
2.4.2 Why Resilience and Adaptive Capacity? 26
2.4.3 The Need for Vulnerability Mapping 29
   2.4.3.1 Coastal vulnerability mapping benefits 30

2.5 The Primacy of Planning 31
2.5.1 Enhancing Preparedness and Awareness 31

Chapter 3 CASE STUDY: THE COAST OF GOZO

3.1 Chapter Outline 34
3.2 General Overview 35
3.3 Overview of Physical Determinants 37
   3.3.1 Coastal Geology and Geomorphology 37
   3.3.2 Climate of the Maltese Archipelago 41
3.4 Overview of Anthropogenic Agents 42
   3.4.1 Coastal Community Setting 42
   3.4.2 Cultural Heritage 43
   3.4.3 Coastal Infrastructure 43
   3.4.4 Recreational Facilities 44
3.5 Coastal Hazard Events in Gozo 45
   3.5.1 Management Frameworks 48
### Chapter 4  RESEARCH METHODOLOGY

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>Chapter Outline</td>
<td>51</td>
</tr>
<tr>
<td>4.2</td>
<td>Methods of Data Collection</td>
<td>52</td>
</tr>
<tr>
<td>4.2.1</td>
<td>Primary Data Techniques</td>
<td>52</td>
</tr>
<tr>
<td>4.2.1.1</td>
<td>Questionnaires</td>
<td>52</td>
</tr>
<tr>
<td>4.2.1.2</td>
<td>Interviews with professionals with relevant areas of expertise</td>
<td>54</td>
</tr>
<tr>
<td>4.3.1.3</td>
<td>Vulnerability scoring criteria</td>
<td>54</td>
</tr>
<tr>
<td>4.2.2</td>
<td>Secondary Data Techniques</td>
<td>58</td>
</tr>
<tr>
<td>4.3</td>
<td>Methods of Data Investigation</td>
<td>59</td>
</tr>
<tr>
<td>4.3.1</td>
<td>GIS – Geographic Information System</td>
<td>59</td>
</tr>
<tr>
<td>4.3.2</td>
<td>SPSS – Statistical Package for the Social Sciences</td>
<td>59</td>
</tr>
<tr>
<td>4.3.3</td>
<td>Visual Analysis Techniques</td>
<td>60</td>
</tr>
<tr>
<td>4.4</td>
<td>Constraints Encountered</td>
<td>61</td>
</tr>
</tbody>
</table>

### Chapter 5  INTERPRETATION OF RESULTS AND ANALYSIS

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>Chapter Outline</td>
<td>62</td>
</tr>
<tr>
<td>5.2</td>
<td>Interpretation of Vulnerability Maps</td>
<td>64</td>
</tr>
<tr>
<td>5.2.1</td>
<td>Risk Map Evaluations</td>
<td>64</td>
</tr>
<tr>
<td>5.2.1.1</td>
<td>Tsunami risk on the island of Gozo</td>
<td>64</td>
</tr>
<tr>
<td>5.2.1.2</td>
<td>Sea level rise on the island of Gozo</td>
<td>69</td>
</tr>
<tr>
<td>5.2.1.3</td>
<td>Flooding risk on the island of Gozo</td>
<td>72</td>
</tr>
<tr>
<td>5.2.1.4</td>
<td>Landslide risk on the island of Gozo</td>
<td>75</td>
</tr>
<tr>
<td>5.2.1.5</td>
<td>Storm surge risk on the island of Gozo</td>
<td>78</td>
</tr>
</tbody>
</table>
5.2.2 Summary of Major Risk Zones 81

5.3 Interpretation of Questionnaires 82
5.3.1 Presentation of Main Results 82
  5.3.1.1 Gender bias 82
  5.3.1.2 Age categories and familiarity of terms 83
  5.3.1.3 Knowledge obtained from different sources 83
  5.3.1.4 Vulnerability to any coastal hazards 84
  5.3.1.5 Knowledge level towards the five hazards 85
  5.3.1.6 Preparedness and protection amongst respondents 86
  5.3.1.7 Hazard perceived probability occurrence 88
  5.3.1.8 Provision of information 89
  5.3.1.9 Factors contributing to coastal vulnerability 90
  5.3.1.10 Ways to reduce coastal vulnerability 91
  5.3.1.11 Personal involvement in coastal hazard-related events 92
  5.3.1.12 Public event participation 93
5.3.2 Survey Findings 94

Chapter 6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Chapter Outline 99
6.2 Key Findings 99

The Need for a Sustainable Approach to the Management of Coastal Hazards 101
6.3 101
  6.3.1 Policy Recommendations and Proposals for Gozo 102
    6.3.1.1 Prevention instead of reaction particularly in high risk areas 102
    6.3.1.2 Development of better tools and guidance for decision-making 102
    6.3.1.3 Monitoring in high risk zones 103
    6.3.1.4 Public preparedness and awareness 103
    6.3.1.5 Coastal defence and risk reduction plans 104
    6.3.1.6 Sustainable coastal planning in high risk areas 105
6.4 Concluding Remarks

REFERENCES

APPENDICES
1 Gozo and Comino Map 127
2 Questionnaire 129
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1.1</td>
<td>Gozo Administrative Divisions</td>
<td>5</td>
</tr>
<tr>
<td>Figure 2.1</td>
<td>Population Density vs. Distance from Shoreline</td>
<td>11</td>
</tr>
<tr>
<td>Figure 2.2</td>
<td>Yearly Occurrence of Natural Disasters</td>
<td>13</td>
</tr>
<tr>
<td>Figure 3.1</td>
<td>The Maltese Islands Surrounded by Tectonic Features</td>
<td>35</td>
</tr>
<tr>
<td>Figure 3.2</td>
<td>Geological Map of Gozo</td>
<td>38</td>
</tr>
<tr>
<td>Figure 3.3</td>
<td>Gozo Natural Landscape Units</td>
<td>40</td>
</tr>
<tr>
<td>Figure 3.4</td>
<td>Pluvio-Thermal Plot</td>
<td>41</td>
</tr>
<tr>
<td>Figure 4.1</td>
<td>Extent of Study Area for Landslide and Flooding</td>
<td>56</td>
</tr>
<tr>
<td>Figure 4.2</td>
<td>Extent of Study Area for Sea Level Rise, Tsunami and Storm Surge</td>
<td>56</td>
</tr>
<tr>
<td>Figure 5.1</td>
<td>Geographical Locations</td>
<td>63</td>
</tr>
<tr>
<td>Figure 5.2</td>
<td>Snapshots of the Tsunami Generation from the Eastern Sicily Scenario</td>
<td>65</td>
</tr>
<tr>
<td>Figure 5.3</td>
<td>Snapshots of the Tsunami Generation for the Western Hellenic Arc Scenario</td>
<td>65</td>
</tr>
<tr>
<td>Figure 5.4</td>
<td>Tsunami Risk Map</td>
<td>68</td>
</tr>
<tr>
<td>Figure 5.5</td>
<td>Sea Level Rise Risk Map</td>
<td>71</td>
</tr>
<tr>
<td>Figure 5.6</td>
<td>Flooding Risk Map</td>
<td>74</td>
</tr>
<tr>
<td>Figure 5.7</td>
<td>Landslide Risk Map</td>
<td>77</td>
</tr>
<tr>
<td>Figure 5.8</td>
<td>Storm Surge Risk Map</td>
<td>80</td>
</tr>
<tr>
<td>Figure 5.9</td>
<td>Representation of High Risk Coastal Regions</td>
<td>81</td>
</tr>
<tr>
<td>Figure 5.10</td>
<td>Gender Protection from Hazards</td>
<td>87</td>
</tr>
<tr>
<td>Figure 5.11</td>
<td>Respondents Level of Preparedness and Protection</td>
<td>88</td>
</tr>
<tr>
<td>Figure 5.12</td>
<td>Reason Contributing to Coastal Vulnerability</td>
<td>91</td>
</tr>
<tr>
<td>Figure 5.13</td>
<td>Interest in Public Events</td>
<td>94</td>
</tr>
</tbody>
</table>
## LIST OF PLATES

| Plate 3.1 | Rdum (left) and Valley System (right) in Gozo | 40 |
| Plate 3.2 | Marsalforn (left) and Xlendi Bay (right) in Gozo | 42 |
| Plate 3.3 | Infrastructural Development in Mgarr Harbour (left) and Xlendi (right) | 44 |
| Plate 3.4 | Large Storm Waves at Marsalforn Front | 46 |
| Plate 3.5 | Influence of Storm Water in Xlendi (left) and Marsalforn (right) | 47 |
| Plate 3.6 | Landslide Blocking Coastal Road Linking Marsalforn to Zebbug | 48 |
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 2.1</td>
<td>Vulnerability Definitions</td>
<td>19</td>
</tr>
<tr>
<td>Table 2.2</td>
<td>Factors which Increase or Reduce Coastal Vulnerability</td>
<td>22</td>
</tr>
<tr>
<td>Table 4.1</td>
<td>Personal Details of Respondents</td>
<td>52</td>
</tr>
<tr>
<td>Table 4.2</td>
<td>Tsunami and Landslide Classification Scales</td>
<td>55</td>
</tr>
<tr>
<td>Table 4.3</td>
<td>Sea Level Rise, Flooding and Storm Surge Classification Scales</td>
<td>55</td>
</tr>
<tr>
<td>Table 4.4</td>
<td>Coastal Vulnerability Criteria</td>
<td>57</td>
</tr>
<tr>
<td>Table 5.1</td>
<td>Gender Bias</td>
<td>82</td>
</tr>
<tr>
<td>Table 5.2</td>
<td>Familiarity of Terms Compared with Age Groups</td>
<td>83</td>
</tr>
<tr>
<td>Table 5.3</td>
<td>Knowledge Provided from Different Sources</td>
<td>84</td>
</tr>
<tr>
<td>Table 5.4</td>
<td>Coastal Vulnerability from Any Five Hazards</td>
<td>85</td>
</tr>
<tr>
<td>Table 5.5</td>
<td>Respondents Level of Knowledge Compared with Age</td>
<td>86</td>
</tr>
<tr>
<td>Table 5.6</td>
<td>Perceived Probability of Occurrence</td>
<td>89</td>
</tr>
<tr>
<td>Table 5.7</td>
<td>Provision of Information from Responsible Authorities</td>
<td>90</td>
</tr>
<tr>
<td>Table 5.8</td>
<td>Methods to Lessen Coastal Vulnerability</td>
<td>92</td>
</tr>
<tr>
<td>Table 5.9</td>
<td>Participation in Coastal Hazard Events</td>
<td>93</td>
</tr>
<tr>
<td>Table 6.1</td>
<td>Summary of Main Hazard Impacts</td>
<td>99</td>
</tr>
<tr>
<td>Table 6.2</td>
<td>Summary of Hazard Risk Areas</td>
<td>100</td>
</tr>
</tbody>
</table>
Chapter 1

INTRODUCTION

1.1 CHAPTER OUTLINE

This chapter provides a short description of coastal vulnerability and describes the aims, purpose of study and the actual site featured in this research. This chapter is then concluded by an outline of the structure of the dissertation.
1.2 TOPIC RESEARCH

Of all inhabited regions by human beings, coastlines are the most urbanised and intensely used locations (Breton, 2004). Over 60 per cent of the world’s population is estimated to live in close proximity to the coastline (Doukakis, 2005). Being the most dynamic environments on earth, the coastal zone is where land and sea interact; thus, coastal locations are under highly intense pressure either from natural and/or human sources, namely unsustainable use of coastal resources, overpopulation and unrestricted development (Kay and Alder, 1999). Despite the fact that coastal areas are under constant pressure and are vulnerable to numerous threats by human activities, coasts provide a unique habitat for several plants and animal species (Beatley et al., 2002).

Characterised by very sensitive ecosystems, coastal habitats include mangroves, reefs, beaches, dune systems and wetlands (UNEP, 2006), many of which provide valuable ecosystem services.

Worldwide and throughout history, coastal zones have been severely exposed and at risk to impacts from multiple hazards. However, in recent times, the impact of hazards on coastal areas has become a matter of great concern, particularly in the light of recent devastating natural catastrophes and human disasters. An earthquake in the Indian Ocean of 2004 triggered a tsunami which claimed the lives of more than 200,000 people, leaving more than one million homeless while destroying several coastlines thousand of kilometres away (Margesson, 2005). Subsequently and only eight months later, the second disaster (Hurricane Katrina) devastated numerous areas in the U.S. Gulf Coast in 2005. The city of New Orleans experienced catastrophic flooding with the consequent deaths of hundreds of people, while several other residents lost their homes (Johnson, 2006). These two events, in conjunction with other minor ones, highlighted three aspects: (i) the power of nature, (ii) the particular vulnerability of coastal regions, and (iii) the emergent need for risk management to safeguard human lives and property.

Hazard risk has become a major challenge for the international community (OAS, 2004). As discussed by Munich Re (2000), since the 1960s natural disasters have increased threefold, whereas economic losses and the total amount of damage sustained have increased eightfold. Coastal hazard threats, impacts and consequences on societies
can never be referred to as one-time events, particularly given a significant increase in frequency and intensity (Munich Re, 2005). Global climate change is further contributing to this problem, likely increasing the occurrence of extreme weather events. Hence, with different areas susceptible to different coastal hazards to varying degrees, an understanding of vulnerability, both in physical and in social terms, is a key consideration for planning appropriate mitigation (Krishna, 2005).

Coastal vulnerability is the degree to which a given hazard would impact a coastal zone. This illustrates how coastal societies and the natural system are in one way or another susceptible to coastal hazards (Kaiser, 2007). Often, the impacts of coastal hazards are most severe when coastal zones are inadequately prepared. This lack of preparedness normally results in fatalities, damage to infrastructure and buildings, and substantial economic losses. Hence, a crucial step in being prepared for the eventuality of coastal hazards before any techniques can be applied is to know which areas are at most risk, and to what hazards (Cottrell et al., 2001).

Resilience and adaptive capacity are two crucial factors in coastal vulnerability. The severity of impacts resulting from coastal hazard events is a function of both of these factors. The inherent ability of a coast to accommodate changes induced by coastal hazards while maintaining the longer-term functions of the coast constitutes coastal resilience (Eurosion, 2004) whereas adaptive capacity is how coastal zones are able to adopt, respond, and improve to different impacts and hazards (Gallopin, 2006).

Since the coastal zone is one of the most important human spheres of action, increasing efforts to handle coastal hazards and risk is necessary to develop adequate monitoring, early warning systems and measures to protect property and human beings. Consequently, to assess hazard risk, the knowledge of vulnerability of coastal areas is crucial.
1.3 AIMS AND OBJECTIVES

Coastal hazards are a matter of concern due to their potential impact on the world’s coastal zones, including the Maltese Islands. Two key questions served as a basis for this research:

1. What is the hazard potential in the coastal zone?
2. Is there enough foresight and knowledge available about the actual hazards and enough awareness-raising concerning personal protection from the cognizant authorities?

Hence, the focus of this research lies in investigating coastal vulnerability to different hazards. In this respect, the vulnerability of the coast of Gozo to five key hazards (tsunami, storm surge, sea level rise, flooding and landslide) is examined in order to identify which areas are likely to be most at risk.

To date, from a local perspective, coastal hazards have received little attention since there are limited studies on this subject. Indeed, this research seeks to redress the balance by addressing five specific objectives. These include:

1. identifying factors that make an area vulnerable and at risk, with particular reference to each of the five hazards;
2. identifying the extent to which each of these hazards presents a threat along the coastline of Gozo;
3. producing overlay data using GIS in order to identify areas most at risk to multiple hazards;
4. investigating whether the locals are aware of and prepared to deal with any of the five hazards in question;
5. developing recommendations which address coastal vulnerability and contingency planning to the above mentioned hazards.
1.4 CASE STUDY AREA

As a sister island of Malta, Gozo possesses a land area of only 67.1 km² (26 sq mi). Its approximate geographical coordinates span from 36°04’26.63”N to 36°01’58.55”N and from 14°11’06.60E to 14°20’12.33”E.

Through time, anthropogenic activities have modified and shaped the island of Gozo as it is known today (Cassar, 2010); namely subdividing it into 14 main settlement areas (Figure 1.1). On a general note, a large percentage of the island’s land cover is devoted to agriculture practices interspersed with discontinuous urban fabric (MEPA, 2010b).

In Gozo, the coastal zone is of significant importance. It is characterised by coastal cliffs dominating mainly the western and southern parts of the island, and also low lying areas where several popular bays and beaches are located. While coastal areas are known for their picturesque and aesthetic landscapes, biodiversity richness, and natural features, they are also the revenue source for major economic and recreational activities taking place on the island of Gozo. As a result, the littoral has probably suffered most
from human pressures. Since the late sixties, coastal zones have become more accessible to road construction, coastal development and tourism especially in the vicinity of Xlendi, Mgarr and Marsalforn. Due to the intensity of use, any impacts deriving from coastal hazards are likely to exert a significant influence.

The island of Gozo could potentially be affected by a variety of coastal hazards. Its topography makes it vulnerable to hazards such as storm surges, tsunamis, flooding, landslides and sea level rise to different degrees. Throughout different periods in time, the coastal zone was influenced by various coastal hazard events that have left an impact on Gozo. In spite of the fact that only a small number of fatal accidents were ever recorded, such coastal hazards caused several consequences on this littoral zone, especially socio-economic impacts. Indeed, from 1693 to the present day, a number of coastal hazard events were recorded (Inguanez, 2000). Low-lying coastlines appear to be at most risk from coastal hazards. In this respect, ground floor buildings, recreational facilities, yacht marinas and port facilities, roads and other infrastructures are amongst those anthropogenic features that are susceptible and vulnerable to coastal hazards.

Since Gozo is not self-sufficient in terms of infrastructure and supplies (e.g. there is no power station on Gozo), its isolation could potentially be an aggravating factor in the event of the occurrence of hazards. In this respect, this coastline serves as a good case study for the researcher to investigate high risk zones in case of a coastal hazard occurrence. Since there seem to be a lack of data available on this subject and insufficient awareness and preparedness amongst the population of Gozo, this case study will hopefully fill a ‘gap’ and may thus be useful for policy makers to develop plans to mitigate the impact of coastal hazards in the Maltese Islands.
1.5 DISSEPTION STRUCTURE

This dissertation mainly consists of six chapters which are outlined below.

Chapter 1: Introduction – this chapter briefly outlines the aim, objectives and background information on the site under study.

Chapter 2: Literature Review – this chapter reviews the literature relevant to this study. Particular reference to coastal vulnerability will be made to explain what makes an area vulnerable to coastal hazards, what impacts each hazard generates and finally the degree of probability of occurrence of these hazards.

Chapter 3: Case study: coast of Gozo – this chapter explores the site being studied including specific details on physical and anthropogenic characteristics and past coastal hazard events.

Chapter 4: Methodology – this chapter outlines all the primary and secondary methods used for investigation, the different analysis techniques and problems encountered while carrying out this dissertation.

Chapter 5: Data Results and Analysis – this chapter presents the main results obtained from the different techniques and a discussion of the findings.

Chapter 6: Conclusions and Recommendations – this chapter outlines the conclusions of the study whilst providing appropriate recommendations in the interest of preparedness and mitigation.
Chapter 2

LITERATURE REVIEW

2.1 CHAPTER OUTLINE

The aim of this chapter is to look into the main themes of this dissertation, and to further expand upon the topic of study, including a survey of prior work. The chapter first provides a short review of what constitutes the coastal zone, followed by a description of the main coastal hazards under study, and a description of coastal vulnerability. The chapter concludes with a discussion of the need for planning strategies.
2.2 COASTAL AREAS: VALUES AND IMPORTANCE

The coastal zone, the boundary where the land meets the sea, is an important and complex environment, integrating both natural and anthropogenic features in the locality. The term ‘coastal boundary’ is not clearly defined and differs significantly amongst countries (Kay and Alder, 1999). It is frequently argued that the land area from the watershed to the sea should also be included with the coastal zone since it is rich in biophysical interactions (Post and Lundin, 1996). Coastal locations are highly dynamic zones due to the constant changing influences of chemical, biological and geological processes, including coastal hazards that shape the coast in both time and space (Clark, 1996).

Nowadays, there is no common or exclusive definition of what constitutes a ‘coastal area’ but rather an assortment of different definitions, each based on different parameters. Some authors define the coastal area from a physical point of view, while others from an anthropogenic aspect. Benoit and Comeau (2005: 305), took a holistic approach in their definition which included both the natural and human aspect of such zones. They claimed that these are:

“areas and specific territories that are influenced physically, economically and socially by strong interaction between land and sea”.

Moreover, Sorenson and McCreary (1990) in Clark (1996: 1) focused their definition more on the physical aspect of the coastal zone, where they pointed out that it is:

“that part of the land affected by its proximity to the sea and that part of the ocean affected by its proximity to the land... an area in which processes depending on the interaction between land and sea are most intense”.

Growing interest and awareness for the coastal zone was seen in the past few years. This interest has evolved from two principal reasons. Firstly, because of the distinct characteristics and features, biodiversity richness and uniqueness of these zones, and secondly, coastal locations are aesthetically pleasurable for local people and foreigners, which contributed to the expanding economic activity (United Nations, 1964).

Coastal zones are unique environments (interaction between marine and terrestrial environments) endowed with distinct features and ecosystems. Therefore, sustainable
development in such regions is of paramount importance as these regions need to be carefully managed for present and future generations. Unfortunately, throughout the world, such zones are amongst the most heavily utilised areas because of their strategic location and rich resources, with resultant impacts on the natural environment (Post and Lundin, 1996). Coastal areas are also increasingly subjected to expansive development and unsustainable use (Klein, 2002). However, not all coastal negative impacts are a result of human pressures; they can also have a physical origin. Natural disasters, climate change effects, and coastal hazards can pose a threat to coastal zones.

2.2.1 Importance of Coastal Areas to Mankind

With the current increasing rate of human pressures on the coastal zones, few of the world’s coastlines are beyond this influence (Buddemeier et al., 2002). The 20th century has witnessed a dramatic boost in the utilization and exploitation of coastlines which continued further on in the 21st century. The coastal landscape has been transformed through not only natural but via a mixture of socio-economic activities including infrastructure development, tourism and recreation, agriculture and aquaculture, and extraction of commodities. These socio-economic activities aim at maximising the economic opportunities of these zones (Valiela, 2006).

Coastal population trends are predicted to increase globally. Nowadays, approximately 3 billion people, over half of the world’s population, live within 60 km of the shoreline. That population is likely to double by the year 2025 (Turner et al., 1996). Indeed of the 17 largest cities around the world, 14 lie along the coastline and these are becoming increasingly urbanised (Tibbetts, 2002). In particular, low-lying coastal areas and small island states are the most popular and densely inhabited locations (Small and Cohen, 1999), thus creating more vulnerable areas (Marfai et al., 2008).

The coastal region is an important environment, which generates both benefits and challenges. High population densities and numerous human interventions in coastal regions have provided many economic benefits though they have contributed to several unacceptable consequences and major impacts on coastal ecosystems (Creel, 2003). Additionally, natural coastal hazards have presented a new challenge that put at risk human lives, assets and infrastructures.
Figure 2.1 show that a large concentration of coastal population is found clustered relatively close to the shoreline and as distance and elevation increases, population densities decrease. The Maltese Islands, including Gozo, show similar trends as coastal resorts are mostly located in low-lying coastal areas.

![Figure 2.1](image)

Source: Nicholls and Small, 2002.

2.2.1.1 Tourism and recreation

Tourism is regarded as one of the most important and fastest growing industries of the global economy. In various instances this industry ranks first in several countries local GDP. Coastal tourism has increased since the end of the Second World War and is said to dominate the economic sector of several coastal regions and small island states (Miller et al., 2002) including Malta. For instance, 95 percent of the economy of Maldives is derived from tourism (Brown et al., 2002). Moreover, coastal zones offer diverse opportunities for recreation activities including fishing, swimming and diving.

Apart from the economic and recreational benefits, Post and Lundin (1996) stated that this sector contributes to a large extent to coastal-use conflicts and management problems. Environmental degradation at various levels around the coastal area is of major concern. With coastal tourism growth in the last decades, development as infrastructure has replaced the natural environment to accommodate high tourist levels.
All of these effects have resulted in biodiversity reduction and resource depletion (Clark, 1998). Briguglio and Briguglio (1996) claimed that several impacts can be noted on the environment from coastal tourism development in Malta, such as waste generation, increasing infrastructure, building demand, and high tourist densities.

2.2.1.2 Coastal infrastructure

Another utility for coastal areas is infrastructure. Despite the big labour opportunities provided to coastal populations, such industries benefit from access to low-cost transportation means. However, some of the critical impacts caused include land reclamation and dredging to make available space for ports and harbours, along with oil and chemical spills. Although emergency procedures and contingency plans are on the increase to control oil and chemical spills from tanker ship accidents, these spills are a continuing danger to coastal shores (Kay and Alder, 1999). Roadways, airports, bridges and other coastal development infrastructure cause other problems. Most often these disturb ecosystems, obstruct stream water flow, and modify the landscape. On the other hand, toxic wastewater discharges including radioactive waste and heavy metals from heavy industries not only cause further environmental damage but also put at risk human health (Clark, 1996).

2.2.1.3 Coastal biodiversity

Coastal ecosystems are among the most productive, yet threatened and endangered environments in the world. Considered as highly imperative regions for their uniqueness and sensitivity (UNEP, 2006), these ecosystems encompass a wide range of terrestrial and marine species (Laurett et al., 2001). Coastal ecosystems are undergoing environmental decline, and high population densities play a significant role. Unless appropriate management schemes by governments and coastal users are appointed, coastal habitats are at higher risk (Creel, 2003).
2.3 CAUSES AND DYNAMICS OF COASTAL HAZARDS

Natural hazards are constant threats (Middelmann, 2007). Coping with natural hazards is a critical factor of how human settlements and resource use have developed since coastal hazards are an ongoing part of civilisation (Adger et al., 2005). All communities including coastal societies be they rural or urban, are prone to, and at risk from certain types of hazards. Until recently, a major conceptual shift in how human beings seek to cope with natural hazards is witnessed. Hence, to understand what makes social, economic and environmental resources prone to hazards and what can be done to combat such affairs is critical to humans and societies (UN/ISDR, 2002).

In part of Munich Re’s insurance research (2005), the occurrences of different natural hazards were investigated worldwide. As illustrated in this chart (Figure 2.2), the frequency and intensity of various hazards has substantially increased from 1950 to 2005. Hence, this confirms that populations and their assets are at greater risk from catastrophes (Munich Re, 2005).

![Figure 2.2
Yearly Occurrence of Natural Disasters](source: Munich Re, 2005)

Coastal hazards are highly dynamic (Zou and Wei, 2010) and with varying impending impacts at different degrees. Global organisations and countries call for a greater
knowledge of hazard characteristics which requires additional and more focused research in terms of their nature, history and effects (UN/ISDR, 2002). However, not all natural hazards lead to disasters and/or catastrophe. For instance, coastal cliff erosion may not be a significant hazard in an abandoned area, but is important in an urbanised zone (NZCCO, 2004). These events only turn into disasters when human lives, socio-economic goods or ecological commodities are affected in one way or another (Birkmann, 2006).

For this reason, one needs to distinguish between hazards and disasters. According to Cambers (2001: 43) a coastal hazard is defined as

“...the occurrence of a phenomenon, which has the potential for causing damage to natural ecosystems, buildings and infrastructure”.

Whereas as defined by UN/ISDR (2002: 24), natural coastal disasters constitute

“...a serious disruption of the functioning of a community causing widespread human, material, economic or environmental losses which exceed the ability of the affected community to cope using its own resources”.

Megacities located within coastal areas are highly vulnerable to natural and man-made disasters (Kotter and Friesecke, 2009). As coastal zones have high population densities, infrastructures and urbanisation, the risk of coastal hazards is twofold and constantly increasing especially in disaster-prone areas (Kaiser, 2006). In this respect, past experience has shown that, to greater or lesser extent, humans in many coastal areas are vulnerable to hazardous events, including events like Indian Ocean tsunamis of 2004 and hurricane Katrina of 2005 (Klein et al., 2002). Consequently, anthropogenic factors can increase the risks of coastal hazards, for example the removal of coastal vegetation, dredging of harbour entrances, and extraction of coastal material which reduces buffering to storms renders these coastal areas more vulnerable to coastal hazards (NZCCO, 2004).

Furthermore, each coastal hazard is categorised by its severity and frequency of occurrence which vary from one country to another (Krishna, 2005). Asia, in the last few decades has witnessed a considerable increase in the frequency and severity of major natural hazards that have drastic repercussions on the social and economic pillars (World Bank et al., 2009). Yet, different coastal hazards have their own characteristics
in terms of severity and frequency of occurrence (Krishna, 2005). In fact, storm surges and tsunamis are considered to be rapid-onset events with moderate to severe consequences at a specific point in time whereas mild flooding can occur frequently. Other hazards like coastal erosion, sea level rise and coastal pollution are considered as chronic processes occurring over longer duration with mild to severe impacts (Kelman, 2007). On the contrary, infrequent events with limited probability of occurring pose the greatest risk on coastal zones as well as the longest time needed for recovery. Ongoing hazards such as environmental degradation can be easily monitored to minimise risk along the littoral, these still threaten such zones (US. Indian Ocean Tsunami Warning System Program, 2007).

In recent years, climate change effects driven by greenhouse gas emissions have become more pervasive, leading to an increase in risk, magnitude and frequency of hazards (Klein, 2002) which is arguably linked to a rise in global temperature. Coastal areas are amongst the locations expected to be most severely affected by climate change phenomena. As explained in the IPCC special report (IPCC, 1997: 5)

“... coastal systems should be considered vulnerable to changes in climate”.

The current rate of coastal development, is amplifying vulnerability to climate change influences which in the long term have major consequences such as beach erosion, disturbance of coral reefs and mangroves, tourism economic losses and damage to infrastructure (Abuodha and Woodroffe, 2006). The Australian coastline, for example, is highly affected by climate change issues (Parvin et al., 2009). Consequently, since a large percentage of population lives along coasts especially to low lying areas, climate change impacts are of major concern.

2.3.1 Risks of Coastal Hazards

This dissertation focuses on five selected coastal hazards, namely storm surge, coastal flooding, tsunami, landslide and sea level rise. Each hazard will be individually evaluated and described with particular reference to their main impacts.
2.3.1.1 Storm surge

Storm surges are characterised by a water level that is temporarily considerably higher than the average high tide line. Such episodes are frequent and among the more predictable coastal hazards that occur in various regions of the world. These are generally produced by high winds and low barometric pressures. Hurricane Katrina in 2005, for instance, generated an 8.2m storm surge which infiltrated up to 10km inland and across a beach front of up to 20km (Belfiore et al., 2009). Due to the wind forces swirling around a storm, a storm surge is merely seawater that is pushed towards the shore (FEMA, 2009). Moreover, influential factors that precipitate storm surge occurrence include wind direction, coastal type and sea depth, and astronomical phenomena (Bryant, 2005).

Apart from the threat to humans which in some instances leads to deaths, storm surges are highly destructive with a high damage potential as they cause coastal erosion, and damage to property and infrastructure. Hence, storm surges are considered a determining factor for flood risk in such zones worldwide (Munich Re, 1998). In this respect, the greatest impact is in low-lying areas (Belfiore et al., 2009).

2.3.1.2 Coastal flooding

Coastal flooding is one of the most common environmental hazards and can occur in different forms. Flash floods are one of the main causes resulting from heavy precipitation in a short period of time, and have been known to flood a sizeable area for several days (US. Indian Ocean Tsunami Warning System Program, 2007). Indeed, this was the case in Xlendi, Gozo on 4th October 2005. This event resulted in damage to vehicles and property. Moreover, flooding could result from rising sea level especially in coastal wetlands, deltas and in low lying coastal areas (Cohoon et al., 1999) or flooding could be produced from storm surge or tsunami. Although this hazard-type is not a long-term event it still causes substantial damage (Kaiser, 2006).

Nowadays an estimated 200 million people or about 4 percent of the world’s population (Nicholls et al., 1999) live in coastal flooding risk zones while an additional 10 million people each year are affected directly by coastal flooding (Nicholls, 2004). With the
current rate of rising coastal population growth along the littoral, the risk of coastal flooding is increasing. For instance, New Zealand is highly vulnerable to coastal flooding. As most of its coastal communities are situated near rivers and shorelines, the risk of high tide and river flooding is high (Huang, n.d).

2.3.1.3 Tsunami

The term Tsunami, is derived from two Japanese words: *tsu* (meaning harbour) and *nami* (meaning waves). Tsunamis comprise a series of waves of considerable length and period (wave-period), which can travel up to 10,000km (Munich Re, 1998). Tsunamis may be caused by (underwater) earthquakes at sea, as well as by submarine landslides, volcanic eruptions and coastal rock falls (Bryant, 2005; Mondello, 2007). In deep oceans, the wave height is rather small but as these approach coastal areas, it can increase to more than 10m in height especially in low-lying zones where the majority of coastal settlements are found (US. Indian Ocean Tsunami Warning System Program, 2007). For instance, tsunamis reaching heights of up to 30m waves have been recorded in Japan (Munich Re, 1998).

Evidence of tsunami occurrence in the Mediterranean Sea is quite strong. This can lead to potential catastrophic events (Mondello, 2007). Tsunami vulnerable areas are at high risk of flooding, economic losses, damage to infrastructure, loss of lives and erosion. Moreover, lack of understanding on tsunami hazard, and the construction of buildings with weak foundations are other factors contributing to tsunami vulnerability (Papathoma and Dominey-Howes, 2003). During the period between 1983 and 2001, 157 tsunamis were recorded worldwide and 16 involved fatalities (Lander et al., 2003). The recent Indian Ocean tsunami in 2004 was perhaps the most devastating tsunami recorded in recent history (Grilli, 2007), causing extensive damage and human losses along several areas of the Sri Lankan and Thai coastlines. This tsunami showed that the world’s coastlines are not prepared for such a hazard (Mondello, 2007).

2.3.1.4 Landslide

Coasts are also vulnerable to landslides. These are caused by slope and cliff instability which often results in the movement of large masses of earth, rock and debris down a slope by different processes including topple, slide and fall (Glade and Crozier, 2005).
Depending on the size of the landslides, these can move at slow to high speed causing various impacts along the way. However, landslides may also be a secondary outcome triggered by earthquakes and heavy storms (NEMO, 2006). Climate change also affects the occurrence of landslides as heavy rainfall intensity reduces slope cohesion (UNU, 2006). The impact of such an event depends on the specific nature of the landslides (OAS, 1991). In Europe, between 1903 and 2004, 75 major coastal landslide events were documented (UNU, 2006). Landslide hazards are responsible for damage in public and private infrastructure, loss of life and injury to people and other assets (Papathoma-Kohle et al., 2007) while coastal settlements built on steep slopes, cliff tops and/or valley bottoms are highly vulnerable to landslides (NEMO, 2006). For instance, since blue clay slopes are a major outcrop in several coastal zones in Gozo, this could increase the risk of landslides and damage coastal settlements.

2.3.1.5 Sea level rise

In the coastal zone, people have been adapting to changes imposed by different hazards, but sea level rise is rather different (Cartwright, n.d). Rising sea level, known as a progressive hazard (Belfiore et al., 2009), is influencing most of the world’s coastlines. During the 20th century, global sea level rise rose by 10cm and is forecast to increase further during the 21st century due to global warming (Nicholls, 2003). Since high natural and socio-economic values are concentrated in proximity to coastal zones, sea level rise impacts are high (Turner et al., 1996).

Vulnerability from sea level rise is significant and on the increase (Nichols, 2003). In particular, low lying areas and small island states are the most at risk from such a hazard (Kaiser, 2006). In fact, around the world, a large number of small islands have disappeared due to an increase in sea level rise. Others, such as Tuvalu Islands and Maldives are at increasing risk of reducing in size (Morner, 2007). When one considers the Gozitan situation, all the coastal resorts are all located within low lying areas, where rising sea level could have a negative impact. Moreover, socio-economic impacts from rising sea level include increase in flood risk resulting in property loss and coastal habitat that are in close proximity to the shoreline, space reduction for recreation, transport facilities and tourism, and finally poor water and soil quality, due to saltwater intrusion, to maintain agriculture and aquaculture (McLean et al., 2001).
Undoubtedly, a fundamental task that present societies must tackle is the protection of the socio-economic and natural values found in the coastal zones and the identification of the level of vulnerability and risk to hazardous features to which coastal zones may be exposed (Oliver-Smith, 2009). Nowadays, coastal hazard research has focused much of the attention on the analysis and determination of the physical characteristics of coastal vulnerability, with relatively limited reference to social indicators (Boruff et al., 2005). In fact, it is not enough to only understand the implications of different hazards, but also the level of vulnerability of how people and the environment are affected (Kaiser, 2006). Similarly, Vellinga and Klein (1993) claim that the primary stage in properly controlling a hazard is to understand the implications of the threat and the nature of vulnerability of this hazard.

The term “vulnerability” has been defined and interpreted differently throughout various literatures and research communities (Das, 2009). Typically, vulnerability is a multidimensional concept encompassing political, ethical, biophysical and socio-economic factors (Nallathiga, 2006). To date, although this concept is commonly used, no consistent explanation of vulnerability exists (Dolan and Walker, 2004). As Cutter (1996: 530) added:

“...vulnerability still means different things to different people”

Some of the most common definitions of vulnerability provided by different authors as adapted by Green (2004: 323) are listed in Table 2.1.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Definition of Vulnerability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yamanda et al., 1995</td>
<td>The potential for attributes of a system to respond adversely to the occurrence of hazardous events.</td>
</tr>
<tr>
<td>Clark et al., 1998</td>
<td>The extent to which a given hazard would impact on a property by reason of its materials or layout.</td>
</tr>
<tr>
<td>IPCC, 2001</td>
<td>The extent to which a natural or social system is susceptible to</td>
</tr>
</tbody>
</table>
Extrapolating the meaning behind all these definitions listed in Table 2.1 leads one to conclude that vulnerability is a composite measure of anticipated impacts and the likely degree to which systems can adapt and respond to these impacts. Despite the fact that coastal vulnerability studies are all the time increasing, a critical limitation in such studies is the fact that only reference to vulnerability at a macro scale is taken into account, omitting micro scale studies which are more useful to policy makers (Das, 2009).

Trans-disciplinary research in assessing vulnerability is becoming widely acknowledged (Post et al., 2007). In the past few decades, vulnerability was not an important concept in coastal research (Hinkel and Klein, 2006). Several coastal vulnerability studies have been based on the social and physical scientific viewpoints on the value of resources and nature of change. In fact, to the ecologist, the concept of vulnerability is linked to coastal biodiversity and functional redundancy of the species to the ecosystem. From a geomorphological viewpoint, vulnerability is linked to relaxation periods, that is, the time required for a system to adjust morphologically to a change, reform and stabilize over spatial and temporal scales (McFadden and Green, 2007). In other perspectives, engineers assess vulnerability in quantitative terms by means of the level of structural damage or harm resulting from an event that could jeopardise the integrity of coastal communities (Hinkel and Klein, 2006). Finally from a social science point of view, vulnerability is mostly conditioned by settlement and populations patterns inhabiting an area (McFadden and Green, 2007).

2.4.1 The Importance of Coastal Vulnerability

Nowadays, coastal zones are vulnerable and susceptible to different coastal hazards to varying degrees (Krishna, 2005). The devastating impacts of recent events raised important questions and concerns as to the intensity of vulnerability of coastal communities to coastal hazards (McFadden et al., 2007). A critical requirement in

<table>
<thead>
<tr>
<th>IPCC, 2002</th>
<th>The degree of incapability to cope with the consequences of climate change and accelerated sea-level rise.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Source: Green, 2004: 323</td>
</tr>
</tbody>
</table>
assessing the hazard potential from coastal natural events is the need to identify and measure those elements that contribute to it (Boruff, 2005). Risk and vulnerability are two critical elements (UN/ISDR, 2002). Hence, assessing coastal vulnerability is a significant requirement in determining which areas are at high risk and why they are at risk (Kaiser, 2007). People are considered to be the most vulnerable and at risk when they are not aware of the threat imposed by hazards on their lives and assets. Kasperson and Kasperson (2001) argued that risk is the likelihood of an event to occur, which as Briceno (2002: 6) further added, is:

“...rooted in conditions of physical, social, economic and environmental vulnerability that need to be assessed and managed on a continuing basis”.

Thus, risk can be termed as the likelihood of consequences resulting from the interaction between hazards and vulnerable/capable conditions (UN/ISDR, 2002):

\[ \text{Risk} = \frac{\text{Hazard}(H) \times \text{Vulnerabilit}(V)}{\text{Capacity}(C)} \]

Since the 1990s a major effort in developing appropriate methodologies and guidelines to assess coastal vulnerability has been made. Klein and Nicholls (1999) explained that coastal zones are considered extremely vulnerable. The level of vulnerability of coastal zones depends on natural and socio-economic factors including human settlement, values and resources and the level of adequate risk management strategies. Coastal vulnerability as defined by Kaiser (2007) is

“...the susceptibility of the natural systems and of coastal societies towards coastal hazards. It is a condition resulting from a system’s social, economic or ecological properties and is a function of its natural and social coping and adaptive capacity to adverse impacts, namely its resilience”.

It is extremely important to understand coastal vulnerability. It denotes the susceptibility of a system which is exposed to a variety of external factors that directly or indirectly influence land use and human settlements, infrastructure, populations and the economy. Furthermore, it is equally important to evaluate and conduct extensive studies of the vulnerability and risk of coastal ecosystems (Nallathiga, 2006).

Conversely, coastal vulnerability towards hazards is also influenced by socio-economic and natural factors and their complex interactions (Boruff et al., 2005). The majority of
the world’s coastlines are extensively developed with high concentration of settlements in proximity to the coastline, diverse economic activities and increasing population densities. All of these pressures are considered to be prone and highly vulnerable to impacts (McFadden and Green, 2007) that most often lead to severe consequences. Such consequences might include impact on economic activities that provide employment, loss of human lives (Kumar et al., 2010), and damage to property, amenities and infrastructure (Cartwright, 2008).

A wide range of national, regional and global studies have been compiled to measure and evaluate the level of vulnerability within the littoral system (McFadden et al., 2003). Villagran De Leon (2006: 49) in his studies summarises several factors which lead to vulnerability or else reduce it. Some important factors are listed in Table 2.2.

Table 2.2
Factors which Increase or Reduce Coastal Vulnerability

<table>
<thead>
<tr>
<th>Factors which can lead to the generation of vulnerability</th>
<th>Factors which enhance vulnerability</th>
<th>Factors which can reduce vulnerability</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Habits and traditions</td>
<td>• Increasing population</td>
<td>• Improvement in social networks and livelihoods</td>
</tr>
<tr>
<td>• Inadequate organisation Systems</td>
<td>• Densification of vulnerable areas</td>
<td>• Training and education</td>
</tr>
<tr>
<td>• Lack of responsibility regarding the generation of vulnerabilities</td>
<td>• City expansion and uncontrolled growth</td>
<td>• Urban planning</td>
</tr>
<tr>
<td>• Illiteracy</td>
<td>• Use of inappropriate Technology</td>
<td>• Implementation, enforcement of building codes</td>
</tr>
<tr>
<td>• Use of inappropriate technologies</td>
<td>• Lack of building codes or their enforcement</td>
<td></td>
</tr>
</tbody>
</table>

Source: Villagran De Leon, 2006: 49

2.4.1.1 Vulnerability hotspots

All coastal regions are vulnerable to a series of potential hazards at different degrees depending on the location, altitude above sea level and geomorphological features (Turner et al., 1996). However, several vulnerability hotspots are evident and seem to be at greater risk than others. Small island states are amongst the most vulnerable to hazard occurrence (Huang, n.d.) while Turner et al., (1996) further argued that low
lying coastal regions are as vulnerable as small island states. Sea level rise is amongst the most severe potential hazard that could affect these locations. For instance, only a 0.5m increase in sea level for small islands such as Maldives (Taylor, 2003), will cause large proportion of their land area to be lost (Darwin and Tol, 2001).

Coral reefs, sandy beaches, deltas and estuaries, and soft rock cliffs are also vulnerable to coastal hazards including climate change phenomenon (Nicholls et al., 2007). Other key vulnerability hotspots in coastal areas include:

1. coastal regions dominated by freshwater resources and sensitive coastal systems;
2. coastal zones dependent on tourist-based economies;
3. coastal areas exposed to multiple hazards with limited precautions and defence mechanisms;
4. coastal regions subject to experience adverse temperature rise effects such as ice-dominated coasts;

Besides small island states, some of the most affected geographical locations include Venice, the Mediterranean Basin, Mississippi, the Nile Basin, the Caribbean, Florida, Asian mega deltas and the Arctic coasts (Nicholls et al., 2007).

2.4.1.2 Coastal vulnerability indicators

Social, environmental and economic components functioning together at various levels increase the risk of vulnerability along coasts. In terms of coastal hazards, vulnerability can be classified into three main groups: ecological vulnerability, social vulnerability and economic vulnerability (Kaiser, 2007). As further argued by this author:

1. Ecological vulnerability refers to the disturbance of natural ecosystems along coasts such as coral reefs, mangroves and wetlands from destructive hazards.
2. Social vulnerability takes into account all the social disruption and mortality rates of individuals, communities and societies from coastal hazardous events.
3. Economic vulnerability describes the severe consequences on property and infrastructure damage and low tourist rates from various hazards.
The range of vulnerability indicators to coastal hazards is very broad and different authors favour certain indicators than others. The choice of the appropriate indicators highly depends on different factors including environmental and socio-economic characteristics of every coastal region (Kim et al., n.d). Thus, such indicators can be assembled into vulnerability classes (Kaiser 2006). For instance, social vulnerability indicators include gender, population growth, education, medical services and health and social dependence (Cutter et al., 2003; Cutter et al., 2009). Economic vulnerability indicators incorporate the cost of damage, economic activity, income loss and labour force (UN-ESCWA, n.d) whereas environmental vulnerability indicators comprise loss of biodiversity, the state and extent of resource degradation and ecological value (UN/ISDR, 2002).

These social, ecological and economic variables, together with resilience can be combined simultaneously to generate a single measure known as the Total Vulnerability Index (TVI). The TVI can be obtained by weighting each of the three variables to according to their relevant importance by using sectoral indices: Social Vulnerability Index (SVI), Economic Vulnerability Index (ENVI) and Ecological Vulnerability Index (ELVI). As further argued by Kaiser (2007), weighting also needs to be carried out between sectoral groups. Further to these sectoral indexes, resilience indicators are also a crucial aspect to be taken into consideration, namely socio-economic resilience and ecological resilience. Ultimately, all of these can be added together to build a total vulnerability index (Szlafsztein, 2005).

2.4.1.3 Global, regional and local scale vulnerability assessment

Depending on the research purpose whether it is at national, regional or local levels (Nicholls et al., 1999), scale is of major importance since it is a crucial factor pertaining to the output results of vulnerability assessment (Kienberger and Zeil, 2005). According to Stephen and Downing (2001: 114):

“Good vulnerability assessments must measure the right things, at the right scale, with suitable conceptual underpinning”.

The reason behind a vulnerability assessment study is to achieve coastal sustainability, benefit from appropriate contingency planning and identify areas that are highly
vulnerable (Doukakis, 2005). Therefore, for this study, vulnerability assessment is
categorised according to national, regional and local studies.

Assessing risk and vulnerability from a national perspective, research projects carried
out on a larger scale are mainly employed in climate change studies to identify regions
where collective action is required (Nicholls et al., 1999). For instance, the DINAS-COAST
project (Dynamic and Interactive Assessment of National, Regional, and
Global Vulnerability of Climate Zones to Climate Change and Sea-Level Rise) aimed at
developing an interactive tool to facilitate users to measure coastal vulnerability and to
investigate likely adaptation strategies to sea level rise (Hinkel, 2005). The DINAS-COAST
will help decision makers evaluate better coastal vulnerability to climate
cchange. Furthermore, the DIVA (Dynamic and interactive Vulnerability Assessment)
tool, a useful tool developed from the DINAS-COAST, is used to generate reliable
quantitative information in exploring the cost and benefits of coastal adaptation options,
the effects of climate change on coastal environment and communities, and to use the
results for policy analysis (Klein and Amanatidis, 2004).

Vulnerability assessment studies from a regional perspective are by far the most
deliberate. A number of analytical approaches have been used to assess coastal
vulnerability but the most common method is the Coastal Vulnerability Index, CVI
(Gornitz et al., 1997). Pendleton et al., (2006) stated that this tool proved to be useful in
evaluating the likely impacts in coastal areas from low to very high vulnerbaility. The
CVI comprises six scaled indicators that strongly influence the coastal zone (Doukakis,
2005) namely geomorphology (a), horizontal shoreline displacement (b), coastal slope
(c), subsidence (d), wave height (e) and tidal range (f). All of these six variables are of
crucial importance since these assist in indicating areas at risk to coastal hazards
(Pendleton et al., 2010).

The CVI calculation (Gornitz et al., 1997; Boruff et al., 2005) is as follows:

\[
CVI = \sqrt[6]{(a * b * c * d * e * f)}
\]

The value obtained from this calculation can be ranked on a linear scale from 1 to 5
where value 1 characterizes the least possible risk of vulnerability whereas value 5
signifies the maximum risk of vulnerability in a given area (Boruff et al., 2005).
Finally, vulnerability studies from a local perspective are the most detailed when compared to national and regional studies (Messner and Meyer, 2005) and focus at community level. To date, coastal vulnerability assessments in Malta have received limited attention since there are limited studies on this subject. However, such local scale assessments have been carried out in many other contexts. For instance, the Micro-scale Risk Evaluation for Coastal Lowlands, MERK-Project is one of the micro-scale damage potential evaluation, which was implemented amongst several locations including the state of Schleswig-Holstein in Germany (Reese et al., 2003 in Messner and Meyer, 2005). This assessment required a detailed site survey of the research area where individual objects were taken into consideration. Amongst other attributes, mapping comprised full overview of every building’s characteristics. The total number of buildings, their function, age, and construction design were taken into consideration.

All of these attributes were useful in determining the likely damages by calculating the valuable objects at risk in relation to the relative depth of damage. Micro-scale results allow for the appropriate planning and strategies that are required to be implemented to minimise risk and vulnerability (Messner and Meyer, 2005).

2.4.2 Why Resilience and Adaptive Capacity?

It is commonly acknowledged that enhancing coastal zone resilience is an appropriate adaptive response mechanism to reduce vulnerability to coastal hazards (Klein et al., 2003). However, for this assumption to be applicable, it is necessary to have a clear understanding of what resilience constitutes, how it can be maintained and by which factors it is determined (Klein et al., 2003). So far, various literatures have expressed the importance of coastal resilience without an appropriate definition and necessary requirements by which it can be improved (Klein et al., 1998).

Resilience according to the UN/ISDR (2002: 24) refers to:

“...the capacity of a system, community or society to resist or to change in order that it may obtain an acceptable level in functioning and structure”.

Blaikie et al., (1994) in his writings provided a similar definition of resilience to natural hazards. Moreover, Carpenter et al., (2001: 766) describes three main properties of resilience. As argued, resilience is the amount of change the system can undergo and
still remain within the same domain of attraction; it is also the degree to which the system is capable of self-organisation and finally resilience is the degree to which the system can build the capacity to learn and adapt. Hence, coastal resilience assesses the capacity of a system to react to the cost of disturbance. Despite the fact that anthropogenic actions often reduce coastal resilience, adaptive capacity helps to increase it (Klein and Nicholls, 1999).

In principle, there are four main attributes of resilience which include latitude, resistance, precariousness and panarchy (Walker et al., 2004). Nowadays there are several means to enhance resilience of the built environment. For instance, retrofitting homes, improving construction practices, elevating homes, and building codes are effective (Cutter, 2008). Moreover, in the coastal zone, two main processes play a major role in determining overall coastal resilience. As argued by Adger (1997), ecological and social systems are both important processes for resilience since these incorporate the ability to withstand external stresses and shocks. A conceptual study of the Dutch coast, conducted by Klein et al. (1998), focused on the combined function of these processes in determining coastal resilience.

The concept of ecological resilience was introduced in the 1970’s with Holling in 1973 defining this term as a measure of determination of systems to absorb change and disturbance (Klein, 2002). Resilience in ecological systems may be indicated by two factors, namely the perturbation and time taken to return to an equilibrium state. Nowadays, ecological resilience is not easily observed since there is no agreed relationship between ecosystem diversity and resilience (Adger, 1997). Furthermore, scale is as an important factor in ecological resilience. Temporal scale is crucial for both the period of disturbance and also the response duration of different species within an ecosystem in the coastal zone (Klein et al., 1998).

Apart from ecological resilience, the concept of resilience in social systems is used to describe the ability of individuals and communities to respond to hazards or other disturbances that interfered with a system’s equilibrium (Kaiser 2006). Insurance, wealth and financial resources, social networks, participation and community engagement are amongst several factors to increase social resilience to coastal hazards (Cutter, 2008). Furthermore, social resilience is measured by means of property rights,
demographic change, institutional and economic structure and finally access to resources (Adger, 1997).

Adaptive capacity (or adaptability), is an element of resilience representing the learning phase of coastal societies and community’s performance and behaviour in response to disturbance (Walker et al., 2007). Hence, a resilient system assisted by adaptive capacity can moderate, avoid, prepare for and also recover from a hazardous event. This term emerged from several disciplines which varies from country to country (Smit and Wandel, 2006). Such a term is frequently applied to coasts, agriculture, business strategies amongst others (Dalziell and McManus, 2004). In this context, adaptive capacity is referred to as (Klein et al., 2003: 38):

“...the ability to plan, prepare for, facilitate, and implement adaptation options”.

According to Dolan and Walker (2004), building adaptive capacity helps reduce vulnerability. Five comprehensive objectives as proposed by Klein et al., (2002: 109) aim at maximising adaptive capacity to reduce vulnerability along coastal zones. Each of these objectives is applicable in this context. These include:

1. Increasing robustness of infrastructural designs and long-term investments
2. Increasing flexibility of vulnerable managed systems
3. Enhancing adaptability of vulnerable natural systems
4. Reversing trends that increase vulnerability
5. Improving societal awareness and preparedness.

Another classification of adaptation options appropriate for the coastal zone as proposed by IPCC CZMS (1990) in Klein (2002) is based on three basic strategies of protecting, accommodating and retreating. These three strategies are appropriate to reduce the risk and probability of an event while increasing the society’s capacity to deal with the impacts of an event. As can be noted, these three adaptation strategies roughly coincide with several objectives as proposed by Klein et al., in 2002.

Various considerations are identified to distinguish the level of adaptive capacity in a coastal zone. As Dolan and Walker (2004) explained, these include the resources available, human capital including security and education, available technological options, the ability of decision making, information available, public participation and
finally stock of social capital. Alternatively the adaptive capacity of coastal societies and communities to manage the various consequences of hazard impacts is considered to be ineffective if there is a lack of physical, institutional and economic power to combat such risks. In addition, even though a high adaptive capacity is set up, it is still ineffective if there is no assurance to sustain actions. As a result, the level of socio-economic exposure to vulnerability remains higher (Luers and Moser, 2006 as cited in Nicholls et al., 2007).

2.4.3 The Need for Vulnerability Mapping

Preparing and assembling a coastal vulnerability map is a fundamental prerequisite to identify specific zones that are vulnerable to one or more coastal hazards (Lakshumanan, 2007). Vulnerability mapping provides the decision makers with precise locations of coastal regions, where people, the natural environment or property are at high risk and could be impact by a catastrophic event (Edwards et al., 2007). By selecting useful indicators and criteria for mapping, such maps will denote the vulnerability at a particular area. Thus, such vulnerability maps if developed in an accurate manner would portray useful information at great depth that can be employed for planning purposes. Mapping attributes include population and settlement patterns, land use, geomorphological features, elevation and terrain, and coastal hazards (WMO, 2009).

Apart from creating vulnerability maps manually using satellite imagery and base maps, coastal vulnerability may be mapped by using practical tools such as Geographic Information Systems (GIS) and remote sensing (Akram, 2005). For instance, GIS are amongst these popular techniques. As the UN/ISDR (2002: 342) explained, these

“…are increasingly being utilised for hazard and vulnerability mapping and analysis, as well as for the application of disaster risk reduction measures”.

GIS are computer-based programs that combine various attributes with spatial data that store, check, update, integrate, manipulate, analyse and finally display such data in the form of maps (UN/ISDR, 2002). In addition, GIS offer a wide range of data analysis, data overlays and data ranking criteria to identify vulnerable hotspots along coastal zones. Such a computer programme is also useful to identify priority areas according to
their relative vulnerability and ranking which giving a high level of importance for mitigation and policy measures (Akram, 2005).

2.4.3.1 Coastal vulnerability mapping benefits

Amongst the diverse benefits that vulnerability mapping offers to coastal societies and communities is the better understanding and visual presentation of the entire coastline, representing areas that are at high risk as opposed to others at lower risk from coastal hazards. Such maps can also allow for prediction and protection beforehand of the areas considered at high risk (Arulraj et al., 2006). For instance, technical experts, rescue teams, local authorities and even coastal settlements can be on the alert about areas that are considered to be at risk (Papathoma-Kohle et al., 2007). If an unpredicted catastrophe occurs causing a considerable amount of damage, such maps can be beneficial to determine which sites need to be evacuated first, where to shift the residents and which evacuation routes are shortest and best accessible to a nearby hospital (Edwards et al., 2007).

Additionally, a major benefit of vulnerability maps is that these can be used in all phases of hazard management whether used for prevention, preparedness, recovery, mitigation, relief, operations, and even for awareness (Edwards et al., 2007). In every phase, planners and decision makers can make wise decisions to avoid high risk zones especially in areas that are highly developed. As argued by Combet (2009: 2), mapping

“...will assist coastal policy makers and planners to develop and implement strategies to prepare for the potential impacts in coastal areas”.

For this reason, appropriate measures can be developed from vulnerability mapping. Coastal embankments to protect roads, stabilising slopes, building dykes to protect harbours, constructing sea walls to prevent damage to structures and fishing boats near coastlines are amongst some of these measures (Edwards et al., 2007). A buffering tool in GIS is a clear example of how vulnerability maps can benefit by identifying which geographical areas including land use zones are affected and to what degree they are influenced. Finally, another benefit of vulnerability mapping is that these can be updated automatically with latest spatial information and other data (Arulraj et al., 2006).
2.5 THE PRIMACY OF PLANNING

Regardless of the fact that various national and local attempts are made to minimise hazard risk and utilize the coastal zone in a sustainable manner, these measures frequently prove to be insufficient and/or inadequate. Consequently, coastal zones are under constant threat and are being degraded continuously (Cicin-Sain and Knecht, 1998). Hence, to overcome both natural and anthropogenic coastal zone impacts, a well organized process to implement decisions, manage and monitor such zones is required. Integrated coastal management (ICM) is considered as a well recognised and promoted process to cope with contemporary and enduring coastal challenges (Klein, 2002).

Integrated coastal management is a multi-phased process that combines various stakeholders including the government and general public in executing an integrated plan to safeguard the coastal zone from excessive impacts of development, conflicts and unexpected hazard events (Belfiore et al., 2009). ICM is very much needed to mitigate and prevent to a large extent natural hazard impacts from occurring, enhance sustainable land use planning to reduce coastal hazard effects while safeguarding coastal resources and communities from tragic disaster events (Clark, 1991).

Coastal land use planning is considered as a key component of ICM. For all coastal hazards, risk can be easily reduced if an effective and appropriate land use strategy is adopted. The development of infrastructures and residential areas in close proximity to the coastline in high risk zones is an obvious scenario which lacks adequate land use planning (Arthoron, 2007).

2.5.1 Enhancing Preparedness and Awareness

With some exceptions, adequate practice to overcome coastal vulnerability is rarely adopted (Devoy, 2008). Over the past years, experience has shown that in both developed and developing countries, inadequate response to the impacts of coastal hazards contributed to severe consequences including loss of lives and destruction to property and infrastructure. Most often, these shortcomings are a result of poor communication systems, inadequacies in legislations, lack of appropriate mitigation and
monitoring, incomplete availability of coastal data, insufficient planning and awareness techniques, and even lack of coordination from the local authorities and agencies concerned (Devoy, 2008). Therefore, adequate preparedness and awareness in the coastal zone need to be in place to minimise the risk to further hazard implications (Letz, 2006).

Amongst several approaches aimed at increasing preparedness and awareness in the coastal zone, public education is a crucial prerequisite in maximising public safety. Nowadays, there is a growing need for adequate education in the coastal zone concerning the diverse hazards especially for living in most vulnerable communities. Awareness programmes in schools and in public venues should provide the public with education materials on coastal hazards, their likely impacts and emergency preparedness planning and techniques to combat such disasters. Schools are vital to prepare and increase awareness. Regardless of the level of education, culture and income, public education ought to be given to address such hazards (WMO, 2009).

Moreover, in the process of data collection to assess the level of coastal vulnerability to hazard risk the general public and community-based organisations ought to be involved in the monitoring and collection of datasets including vulnerability assessments and risk mapping of such regions. This in turn will raise indirect awareness by the public of the need to flee to safer zones where risk is at minimum (Letz, 2006).

Emergency planning and preparedness should be implemented at a national and local level (WMO, 2009). For instance, developing an effective Early Warning System is an important preparedness technique in the effort to reduce risk in vulnerable coastal regions and limit loss of life and property (Munich Re, 2005). Undoubtedly, such a measure helps communities be prepared to evacuate to safer areas when disaster occurs. However, large-scale hazards including tsunamis and earthquakes are perceived as rare phenomenon unlikely to occur. As a result, in several coastal zones alertness and awareness is not given much importance for such hazards. Governments and local authorities concerns ought to give priority to such coastal impacts with adequate means of awareness, preparedness and appropriate strategies (Letz, 2006).
Walker *et al.*, (2007) discussed other ways how to reduce long-term vulnerability of coastal communities. The following is a list of some important measures:

1. Increasing public understanding towards hazards through the use of newsletters, educational programmes, seminars, workshops, and community websites.
2. Enhancing local involvement in the decision-making process to improve community-level responses, planning and coordination between communities in emergency situations.
3. Improving incentives, knowledge, investments and assistance to enhance awareness and participation in improving communications and emergency plans.
4. Enhancing coastal protection of low-lying and exposed coastal areas by building sufficient infrastructure, transportation links and buildings.

As many coastal issues are accompanied by several human interventions which often increase the risk to hazard, an increase in preparedness and awareness would lead to a decrease in risk to coastal hazards.
Chapter 3

CASE STUDY: THE COAST OF GOZO

3.1 CHAPTER OUTLINE

The focus of this chapter is to present a picture of the geographical characteristics, activities, significant features and also the natural diversity of the coast of Gozo. Due to the presence of various physical and anthropogenic assets in close proximity to the Gozitan coastline, coastal vulnerability will, to a certain extent, be an even more significant concern.
3.2 GENERAL OVERVIEW

The Maltese archipelago consists of three main inhabited islands, with a total land area of 316km² namely Malta (area 245.7 km²; length 27km), Gozo (area 67.1km²; length 14.5km) and Comino (area 2.8km²; length 2.5km) and several small uninhabited islets, including Cominotto, Fungus Rock, Filfla, St. Paul’s Islands (Schembri, 1993).

The islands are located within the central Mediterranean region (Figure 3.1), and lying approximately some 96km from the south of Sicily, 290km off the coast of Libya (Cassar et al., 2008), 1836km from Gibraltar and 1519km from Alexandria (Schembri, 1994). Situated on a shallow shelf, the islands form part of a submarine ridge that stretches from the south Sicilian headland to the northern coast of Africa (Cassar, 2010). The average bathymetry depth ranges from 90m to a maximum of 200m between the islands and Sicily while to deeper zones reaching not more than 1000m amongst the islands and North Africa (Spiteri, 1990).

Figure 3.1
The Maltese Islands Surrounded by Tectonic Features

Source: Galea, 2007: 726
Gozo, the island used in this study (refer to Appendix 1 – Gozo and Comino Map), is roughly a quarter of the size of the mainland island (Malta) which lies roughly 8km North of Malta (Ciantar, 2000). With a 42.6 km coastline, Gozo has a maximum distance and width of 14.5km and 7.2km, respectively (Council of Europe, 1991). Despite its small size, Gozo boasts important historic features and traditions. It hosts a population of approximately 30,000 inhabitants that reside in various towns and villages scattered along the island especially in coastal zones (NSO, 2010). On Gozo, as Sultana (2005) explains, 62.0% of the coastline is composed of cliffs, 14.5% of screes, 7.5% of coastal development while inaccessible sites amount to 74.0%.

In various ways, Gozo has a distinct character quite different from Malta (Ciantar, 2000). The picturesque landscapes, remote landforms and physical features, historical artefacts, and settlement patterns, are some of the features that characterize Gozo. The Gozitan coastal zone in the last few decades has witnessed a critical transformation as the natural landscape that used to dominate in the 60s and 70s, shifted to a much bigger urban area dominated by holiday apartments and eating outlets, the result of strong commercial and infrastructural development. Such zones are predominant areas for the local economy especially in the peak summer months.
3.3 OVERVIEW OF PHYSICAL DETERMINANTS

The following physical characteristics of the island may potentially be factors impacting Gozo’s vulnerability to different hazards.

3.3.1 Coastal Geology and Geomorphology

The major rock types outcropping on the Maltese Archipelago belong to different epochs mainly the Oligocene-Miocene period (Said, 2004; House et al., 1961). These rock types are quite simple to identify due to the basic stratigraphic arrangement (Figure 3.2). The different rock types, in order of decreasing age, include Lower Coralline Limestone, Globigerina Limestone, Blue Clay, Greensand and Upper Coralline Limestone (Hyde, 1955). In fact, Gozo has a more varied geology than Malta since it still maintains good exposure of Blue Clay, Greensands and Upper Coralline Limestone. Such strata are located in several sites, especially in the Nadur/Dahlet Qorrot embayment, Ir-Ramla slopes and Mgarr Harbour.

The Lower Coralline Limestone (LCL) is the oldest and lowest formation (Pedley et al., 1976). In Gozo, it is located in vertical cliffs of about 140m along the coastal zone of Xlendi, in areas south of the South Gozo Fault and in the North of Qala point (MEPA, 2001). In fact, it also prevails within several valleys of Wied Sabbar, Wied Mgarr ix-Xini and Wied il-Ghasri (Cassar, 2010). Due to erosion processes on the LCL, karst landscape and sharp lapies are typically formed (Magri, 2006).

Above this geological stratum lies the Globigerina Limestone. This stratum is of high economic important since it supplies most of Malta’s building stone (Hyde, 1955). On Gozo, the Globigerina Limestone forms a broad rolling landscape (Schembri, 1997) which is widely exposed along the western and southern regions and also in valley gorges (Cassar, 2010). When such limestone is exposed to coasts, its continuous erosion by wave action produces low-lying platforms extending seawards. These feature mostly in Xlendi Bay and the Mgarr Harbour region.

Proceeding upwards is the Blue Clay formation. Mainly composed of extremely soft weathered rock serving as an impermeable base for the perched aquifer, it is exposed in...
several areas (Said, 2004). Blue Clay slopes are predominant in the vicinity of Ramla Bay and ix-Xatt l-Ahmar. In Gozo, the maximum thickness of Blue Clay is around 65m located to the North East (Pedley et al., 1976). As a result of Blue Clay slopes, the risk of landslide is on the increase.

Next in the sequence is the Greensand formation which is considered to be the thinnest, rather friable rock formation on the islands (Schembri, 1994). In Gozo, the maximum thickness is 16m in some areas while in other zones it is absent from the geological sequence (Borg, n.d.). Along the Dahlet Qorrot embayment and Xaghra scarp, exposure of such stratum is noted (Cassar, 2010). Further inland, this geological formation is located on the Gelmus Hill where it is predominant (Said, 2004).

The last geological layer is the Upper Coralline Limestone (UCL). Despite its relatively young existence, it is very similar in appearance, colour and components to the LCL formation (Pedley et al., 1976). The UCL is prevalent to the eastern side of the Gozo while largely absent on the western side (Schembri, 1997). In addition, Quaternary deposits, namely cliff breccias and valley loams are another feature in Gozo though limited to a few areas (Trechmann, 1938). For instance, these deposits are easily recognisable since these occur as isolated patches in cliffs and on valley sides such as in the Dwejra area.

![Geological Map of Gozo](image-url)
The island of Gozo is a clear manifestation of a variety of geomorphological features largely characterised by drainage patterns, cliffs and rdum areas, major faults, drowned valleys, sinkholes and low lying coastlines (MEPA, 2005). Topographically, Gozo consists of a series of hills with the highest point of 191m located at Dbiegi (Schembri, 1994). Furthermore, the shores of the western side are dominated by vertical plunging cliffs which exceed over 100m in certain areas while rdum, valleys and low-lying areas predominate to the north and south of the island (Said, 2004).

Distinctive rdum and valley systems (Plate 3.1), significant for their ecological importance, produce a spectacular element along the Gozitan coastline. Rdum areas consisting of ‘quasi-vertical rock faces’ (Cassar, 2010) occur either by tectonic or erosion processes. Located where Blue Clay outcrops at sea level (Magri, 2006), these zones in the coastal shores are surrounded by screees of boulders and other debris that have eroded from the rdum edge due to jointing and faulting. Rdum il-Kbir located between San Blas and Dahlet Qorrot, is considered the most extensive scree formation in the Maltese Islands (Cassar, 2010). Rdum areas are known to provide a superb habitat for many species of flora and fauna since these are mostly inaccessible (Schembri, 1997).

Valley formations (Widien), on the other hand, are drainage channels that are created by erosion, tectonism or a combination of the two. As a result of the low annual rainfall, most of these valleys are dry valleys, which only carry water during the wet season (Schembri, 1993). Gozo hosts quite a large number of valley systems including, Wied Danjel, Wied Bingemma, Wied ir-Raheb, Wied il-Mielah, and others. Some of these lead to pocket beaches that are quite popular amongst the locals (Ebied and Young, 1980). Steep-sided gorge-type valley systems are an example of diversity-rich valley systems in Gozo. Rising sea levels have submerged the mouths of existing valleys along the coastline, which has resulted in an increase in creeks, bays and headlands such as Mgarr ix-Xini and Xlendi Bay (Schembri, 1994). Furthermore, these valley systems are considered as some of the richest habitats on the islands (Cassar, 2010). A wider valley system such as Wied ir-Ramla leading to Ramla Bay is vital for the regeneration of the sediment supply (Rolls, 2006).
Gozo is also characterised by several fault systems. The most dominant fault system on the island is the South Gozo Fault. This runs from the east coast of Ras il-Qala to the southeast coast in Mgarr ix-Xini. Other faults include the Dwejra Fault, Dahlet Qorrot Fault and Xlendi Fault (Hyde, 1955). Moreover, other geomorphological features that are found in the coastal zone include semi-circular coves, arches, caves, tunnels, bedrock platforms, and drop-offs (UNEP, MAP, PAP, 2005). On a general note, the Gozitan coastal area provides an interesting, even picturesque, landscape. Some of the predominant landscape units within this region are noted in Figure 3.3.

Figure 3.3
Gozo Natural Landscape Units

Source: Cassar, generated in 2004; Vogiatzakis et al., 2005: 46
3.3.2 Climate of the Maltese Archipelago

Climate has a significant impact on the Maltese Islands. Chetcuti et al., (1992), presented a detailed review of the climate in Malta. Since the islands belong to a typical Mediterranean climate, one would expect dry summers and mild wet winters (DeKetelaere et al., 2010; Borg et al., 2007). The period between May and September is known to be the hottest, whereas in between October and April temperatures decrease sharply. Climate variability especially rainfall patterns fluctuates from year to year (Attard, 2007). Figure 3.4 represents variations of the total monthly rainfall with mean maximum monthly air temperature during the period of 1st September 2001 to 30th April 2008. The advantage of this plot over a single-year plot is that it shows clear inter-annual variations (Lanfranco, 2010).

To date, due to the maritime nature of the islands, the average annual relative humidity is high, mostly ranging from 65 to 80% (Schembri, 1994). Furthermore, the average annual precipitation amounts to 530mm while the average annual air temperature is 18.6°C (Attard, 2007). Although the islands receive a great deal of sunshine, windy periods account for 92% of the days annually with the most predominant wind being the North-Westerly wind (Majjistral) (Schembri, 1993). Precipitation usually occurs as rainfall, which generally falls in quick, heavy showers. In fact, such rainfall increases the risk of flooding along low-lying areas (Chetcuti et al., 1992).
3.4 OVERVIEW OF ANTHROPOGENIC AGENTS

The entire coastal area surrounding Gozo has witnessed a radical change due to human activity. The following is an account of the most dominant anthropogenic features along the coast.

3.4.1 Coastal Community Setting

As expected, due to high population, coastal zones are under remarkable pressure from various human activities, primarily because of their limited areas, intrinsic attractiveness and geographical characteristics (MEPA, 2010a). Moreover, demographic shifts (rural-urban migration) can be noted between seasons especially winter and summer. In the peak summer months, a large number of locals who own a summer residence stay in two popular coastal resorts, Marsalforn and Xlendi Bay. These two coastal zones are dominated by holiday complexes and apartments packed in the vicinity of the coastal zone (Plate 3.2). These have sharply transformed the natural landscape of the area into an urban congested zone. Conversely, as September approaches, many people return to their permanent homes.

Plate 3.2
Marsalforn (left) and Xlendi Bay (right) in Gozo

Source: Photos taken by writer on 24th July, 2010

Apart from the three-to four-storey holiday apartments, several traditional boat houses, most of them engraved into the limestone, are nowadays being occupied as a summer residence for several families especially those located in Dahlet Qorrot and Mgarr ix-Xini. Moreover, other low-lying bays and beaches scattered along the island that are not
considered summer resorts are also popular amongst tourists and locals who visit them daily. Several coastal zones testify to this trend, including ir-Ramla, Hondoq ir-Rummien and other small bays such as San Blas and Dwejra.

### 3.4.2 Cultural Heritage

The Gozitan littoral zone is also varied in historical and archaeological landmarks dating back to different periods in history (Rolls, 2006). Indeed, coastal watch-towers were built in order to provide security against enemies approaching the island. These coastal towers include Xlendi tower, Dwejra tower, Mgarr ix-Xini tower, Dahlet Qorrot tower, Garzes tower and Marsalforn tower (Samut-Tagliaferro, 1993). Moreover, surrounding the island are two fortifications namely, the Castello and Fort Chambray and several Batteries and Redouts that served similar purposes to the towers (Samut-Tagliaferro, 1993). Such historic structures are all scattered in different coastal locations such as Xwejni Redoubt, Ramla Battery, Ras il-Qala Battery, Mgarr Battery and Marsalforn Redoubt.

The incised cart-ruts cutting across the limestone, Calypso cave, Roman Villa remains and salt pans of various sizes constitute other important historical elements along coastal regions (Farrugia, 2008). Although a large number of these salt pans are not being used, they constitute a prominent feature of the Gozitan coastal landscape. Such salt pans are situated in the vicinity of Xlendi and Marsalforn Bay.

### 3.4.3 Coastal Infrastructure

Coastal infrastructure (Plate 3.3) which has significantly increased over the centuries, has boosted the local economy and led to a decline in numerous coastal habitats (Cassar, 2010). Indeed, the main industrial areas are located in close proximity to the coastline (UNEP, MAP, PAP, 2005). Mgarr Harbour, for example, is an asset for Gozo, acting as a hub for the ferry service that transports people, cars and cargo to and from the island to mainland Malta. It also used for various industrial purposes. For instance, merchandise and wheat are also transported and unloaded in this harbour. Other infrastructure facilities in this area include a ferry terminal, various jetties operated by the yacht marina, two petrol stations for vehicles and another utilised by sea vessels, and finally a main road leading to the centre of the island. Moreover, in the limits of Xlendi,
MEPA granted permission for the placing of a buoy for cruise liners to berth in this area (The Malta Independent, 2008).

Additionally, as part of the Gozo Sewage Master Plan to minimise sewage outfalls at sea, a sewage treatment plant was constructed in the limits of Ras il-Hobz near Mgarr ix-Xini (MRI, 2002).

Plate 3.3
Infrastructural Development in Mgarr Harbour (left) and Xlendi (right)

Source: Photos taken by writer on 24th July, 2010

3.4.3 Recreational Facilities
The coastal waters provide a number of opportunities for scuba diving. It is considered to be one of the major coastal industries, attracting a large number of tourists (Tegge, 2003). Several underwater caves are very popular with divers due to their unique beauty, offering an interesting terrain to discover the maritime world.

Furthermore, the Gozitan littoral is supplemented with a large number of recreational facilities. Apart from various proposed coastal development including Hondoq ir-Rummien and ir-Ramla development plans, the coastal zone is lined with various hotels sited in Xlendi, Mgarr Harbour and Marsalforn, and restaurants, kiosks and bars adjacent to the coastline (refer also to Plate 3.3). All these recreational amenities are considered the hub of the major economic activities that take place as they enhance the local economy especially in the peak summer months, when the tourism industry reaches its peak.
3.5 COASTAL HAZARD EVENTS IN GOZO

Throughout different periods in time, the coastal zone was influenced by various coastal hazard events that have left an impact on the island of Gozo. As a consequence, although only few fatal occurrences were recorded, such hazards had a significant effect on the social and economic sectors within the littoral zone. In the light of the five coastal hazards under study, the most recent hazardous events that heavily impacted the Gozitan coastal zone include:

1. Tsunamis

Historical records reveal that the eastern part of the Mediterranean is more prone to damaging tsunamis than the west, with the strongest tsunamis located in the Calabrian and Hellenic Arc, and Aegean Sea (Camilleri, 2006). As such, the Hellenic Arc and the Eastern Sicilian region are amongst the most critical locations that may affect the Maltese archipelago (Galea, 2007).

Apart from a number of tsunami events occurring in Malta (Savona-Vebtura, 2005), a somewhat significant tsunami, resulting from an earthquake, hit the Xlendi area back in 1693. The sea at Xlendi rolled out to about one mile and swept back a little later with the resultant destructive force typical of a large tsunami (Camilleri, 2005). Nowadays, if a tsunami similar to that of 1693 were to strike at Xlendi Bay, the medium-rise buildings along the coastal promenade would be heavily damaged (Camilleri, 2003). Moreover, another two tsunami-like events occurred on the 28th March and the 28th December 1908. Both were generated by a massive earthquake in the limits of Messina Straits; several waves reached the Maltese shorelines causing flooding and damage to fishing boats and dwellings (In-Nahla, 1909).

2. Storm surge

Most frequent in occurrence, storm surges are common to the island of Gozo. Occurring mostly when there are prevailing strong winds, these surges can be quite destructive. For example, on the 13th December 1967, severe damage was caused to Mgarr Harbour when the pier and breakwater were swept away by the heavy seas. As reported in the Times of Malta (1967) and Il-Berqa (1967) the rough seas caused further damage to
several fishing boats that broke loose from their moorings and were smashed by the incoming waves. Moreover, on the 9th March 2009, Marsalforn front (Plate 3.4) was hit by high waves which caused severe damage in infrastructure including pavements, roads and property.

Plate 3.4
Large Storm Waves at Marsalforn Front

Source: Photos taken by writer on 9th March, 2009

3. Coastal flooding
During winter months, the short, intensive rainfall events, known as flash storms, tends to increase flood rates in various low lying coastlines. Of the various flooding events that occurred in Gozo, some are of particular note. The 28th August 1964 flood caused widespread damage to various coastal zones, in particular Xlendi and Marsalforn (Plate 3.6). As a result of the heavy rainfall that lasted for two whole days, the flooding caused severe damage to roads and infrastructure while some vehicles ended up at sea (Times of Malta, 1964; Il-Berqa, 1964). Moreover, similar to the 1964 event, on the 25th October 1979, flooding caused substantial damage to the Maltese Islands, especially within coastal zones (Inguanez, 2000).

On the 4th October, 2005 and on 11th October, 2010, flooding caused by heavy rainy periods in Xlendi Bay (Plate 3.5), resulted in damage to property and motor vehicles, and other negative impacts on the surrounding environment. On a similar note, on the 29th December, 2007, the beach sediment at ir-Ramla was carved out by the flood waters, creating a thick channel at the mouth of the valley [http://www.abcdesignmalta.com/maltastorms/ as accessed on 21st July 2010].
4. Sea level rise
When compared to the other four coastal hazards under study, sea level rise is known to be a latent hazard as its effects are unnoticeable to the human eye. Over a period of time, various coastal zones seem to be impacted negatively by sea level rise, including low lying coastal areas. To date, the current increase in sea level rise in Malta is acknowledged to be 1cm while it is predicted to rise to 0.5m by 2050 and to 1m by 2100 (MEPA, 2006b).

Evidence of sea level rise in Gozo is explained by Said (2005). As argued, a resultant feature of wave erosion is different landform formations along shore platforms. In the coastal regions of Xwejni, Qbajjar Bay, Dwejra and ix-Xatt l-Ahmar, evidence of sea level rise is noted due to various submerged large marine caves, sea arches and several wave-cut shore platforms in the limits of San Dimitry Point. Additionally, Ramla Bay is at high risk from sea level rise. As predicted, just a 0.5m increase in sea level will lead to a further reduction in beach size (Formosa and Bartolo, 2008).

5. Landslides
Heavy rainfall, cliff instability and blue clay slopes are all factors contributing to an increase in landslides. For instance, the 11th January 1693 earthquake resulted in a landslide in the vicinity of Ta’ Cenc where a substantial large part of the cliff ended up at sea (Inguanez, 2000). A similar landslide occurred on the 2nd March 2009, in the limits of Marsalforn, from Xwejni Bay to Reqqa Point (Plate 3.6). Although this
landslide was not caused by natural dynamics, but was the direct result of the sheer weight of the debris that had been dumped on top of the hillside, such an event contributed to the blockage of the road after heavy rains. Moreover, on the 20th October 2010, a landslide in the vicinity of Xatt l-Ahmar occurred, with the consequence of blocking a path and a substantial amount of blue clay ended up at sea.

Plate 3.6
Landslide Blocking Coastal Road Linking Marsalforn to Zebbug

Source: http://feed.gozonews.com/~r/GozoNews/~3/QZP3ugm1XtA/
[Accessed on 22nd July, 2010]

3.5.1 – Management Frameworks

With reference to coastal hazards, important national and local management strategies concerning this subject were adopted. Hence this section seeks to address essential legislations, treaties and policies in relation to coastal hazards.

3.5.1.1 National strategies

The Barcelona Convention (Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean) aims at safeguarding the marine environment, ensuring sustainable management (UNEP, 2007), and reducing sea pollution in the Mediterranean Sea (EUROPA, 2007). To achieve these goals, seven treaties related to the conservation of the Mediterranean Sea were produced. The ICZM Protocol (the Protocol on Integrated Coastal Zone Management in the Mediterranean) adopted in 2008 is the newest treaty in the framework of this convention (EUROPA, 2009). To date, this is not yet in force as not enough Mediterranean countries have ratified it, including Malta. One of the main objectives (ICZM Protocol, 2008:73) is to:
“prevent and/or reduce the effects of natural hazards and in particular of climate change, which can be induced by natural or human activities”

A specific chapter on the risks affecting the coastal zone (section IV) was produced to address issue related to coastal hazards, prevention, mitigation and adaption measures (UNEP, 2007). Several important strategies (ICZM Protocol, 2008: 83-84) include:

1. Article 22: Natural Hazards
   a. Within the framework of national strategies for integrated coastal zone management, the Parties shall develop policies for the prevention of natural hazards. To this end, they shall undertake vulnerability and hazard assessments of coastal zones and take prevention, mitigation and adaptation measures to address the effects of natural disasters, in particular of climate change.

2. Article 24: Response to Natural Disasters
   a. The Parties undertake to promote international cooperation to respond to natural disasters, and to take all necessary measures to address in a timely manner their effects.

   b. The Parties undertake to coordinate use of the equipment for detection, warning and communication at their disposal, making use of existing mechanisms and initiatives, to ensure the transmission as rapidly as possible of urgent information concerning major natural disasters. The Parties shall notify the Organization which national authorities are competent to issue and receive such information in the context of relevant international mechanisms.

   c. The Parties undertake to promote mutual cooperation and cooperation among national, regional and local authorities, non-governmental organizations and other competent organizations for the provision on an urgent basis of humanitarian assistance in response to natural disasters affecting the coastal zones of the Mediterranean Sea.

3.5.1.2 Local strategies

The Malta Environment and Planning Authority, the agency responsible for both environmental regulations and land use planning in Malta, has published various documents related to the coastal zone. In the 1990s, the Structure Plan for the Maltese Islands was published, providing various policies for different sectors with the aim of combining different characteristics of social, economic and physical structures found within the Maltese archipelago (Malta Structure Plan, 1990). In addition, in 2002, MEPA published the Coastal Strategy Topic Paper to address Integrated Coastal Zone Management in the Malta. In 2006, MEPA published the Gozo and Comino Local Plan in order to provide specific proposal and policies for the entire island of Gozo.
Although such policies and regulations are of high importance and useful to several sectors including the coastal zone, coastal vulnerability and hazard risks are not specifically targeted. In all these publications, little reference is made to such a critical subject. In fact, flooding is the only hazard identified in the Gozo and Comino Local Plan.

However, some indirectly relevant policies and legislations related to coastal hazards obtained from such publications include:

**Gozo and Comino Local Plan** (MEPA, 2006a: 161, 119, 68):

*MEPA shall encourage the formulation of a Management Plant that seeks to:*

- a. Strive to protect the vulnerable habits found in the area according to the levels of protection afforded in scheduling.

*GZ-COAS-1:* The relevant coastal areas may also be safeguarded for their ecological, natural heritage or landscape importance as indicated through policy GZ-RLCN-1.

*GZ-UTIL-8:* Several areas are indicated as areas prone to flooding. MEPA shall only consider request for new development in these areas favourable if they are related to any one of the following:
  - a. water management;
  - b. environmental conservation;
  - c. rural informal recreation; and
  - d. maintenance on existing facilities or future approved structures.

**Structure Plan for the Maltese Islands** (Malta Structure Plan, 1990: 94):

*POLICY CZM 2:* A Subject Plan will be prepared for coastal zone management, to include both conservation of this important resource, and improved facilities for its enjoyment by the public.

*POLICY CZM 3:* Public access around the coastline immediately adjacent to the sea or at the top of cliffs (including in bays, harbours, and creeks) will be secured.

Moreover, the Civil Protection Department (CPD), formerly known as the Malta Police Fire Brigade, has a critical role to play in the organisation of civil defence services. Amongst the several objectives of this Department, the development of emergency plans and the identification of potential hazards including coastal hazards are also taken into consideration (CPD, 2001). Situated in several stations around the Maltese Islands, in case of an emergency, the CPD are equipped with appropriate machinery and vehicles to provide a prompt and effective service.
Chapter 4

RESEARCH METHODOLOGY

4.1 CHAPTER OUTLINE

This chapter highlights the methods and approaches used for the compilation of data. For this study, various data collection methods based on both primary and secondary sources were utilised as explained in the first part of this chapter. In the second part, details of the various techniques used are provided. Concluding this chapter is an outline of all the constraints encountered while this study was carried out.
4.2 METHODS OF DATA COLLECTION

The techniques used for this research comprise the use of primary sources (through questionnaires, interviews, and vulnerability scoring criteria) and secondary sources.

4.2.1 Primary Data Techniques

4.2.1.1 Questionnaires

To understand the level of preparedness and awareness the Gozitan people have, regarding coastal hazards, a questionnaire was distributed addressing five potential coastal hazards, namely tsunami, storm surge, sea level rise, flooding and landslide. The questionnaire was distributed in Mgarr Harbour, ir-Ramla, Marsalforn, Xlendi, Hondoq ir-Rummien and Dahlet Qorrot. 25 questionnaires were distributed in each site, for a total of 150. Since these six coastal areas are frequented more by locals vis-à-vis other areas, the rationale underlying the selection of these regions was to gather a larger local respondent result.

This survey consisted of an interview based on a questionnaire. Distributed and completed on site in a one month period (July 2010), different timeframes for the distribution of questionnaires during the day were used to sample different age groups and male/female respondents. Collectively 86 males and 64 females participated in this survey, spread across different age groups (Table 4.1).

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15-30</td>
<td>30-45</td>
</tr>
<tr>
<td>Male</td>
<td>43</td>
<td>27</td>
</tr>
<tr>
<td>Female</td>
<td>28</td>
<td>23</td>
</tr>
<tr>
<td>Total</td>
<td>71</td>
<td>50</td>
</tr>
</tbody>
</table>

A systematic random sampling technique was used in this research. A decisive benefit of this method is that it involves selecting every agreed interval – n\textsuperscript{th} person (Babbie,
Hence, this is operationally convenient, simple and efficient in sampling a large population (Singh, 2003). In fact, to ensure that a range of age groups and male/female respondents were selected, a uniform coverage was adopted whereby every 5th person was approached and asked to participate in the survey. Nevertheless, if the person selected turned out to be a tourist, or was reluctant to participate, then, the following 5th person would be approached.

The questionnaire (Appendix 2) consisted of 16 closed-ended questions. Closed-ended questions tend to be helpful since they enable the respondent greater control and precision and easier analysis (Arthur, 2006). Moreover, to avoid any difficulties with key terms, the questionnaire took the form of a face-to-face interview, to ensure that all the respondents could easily understand all the questions being asked. The questions aimed at evaluating the level of awareness, preparedness, and level of knowledge among the local population vis-à-vis coastal hazards. With the help of tick boxes, the first two set of questions (A and B) were aimed at determining the respondent’s personal profile, namely gender and age.

In section one, concerning risk perception, questions (1-4) were related to coastal hazards. Question 5 aimed at investigating respondents’ view vis-à-vis the classification of the perceived probability of occurrence of each of the hazards under study. Questions 6-8 focused on the state of provision of information from the competent authorities and on personal protection in case of a hazard occurrence. Question 9 focused on the respondents’ views on what can accentuate coastal vulnerability while questions 10-11 allowed the respondents to give their views regarding the availability of protective mechanisms and to suggest ways of improving these measures.

In section two, the respondents were asked questions related to public participation. Questions 12-14 asked whether respondents ever attended a public event featuring coastal hazards, what type of event it was and if in the future the same respondents would be interested in participating in an event related to this topic.
4.2.1.2 Interviews with professionals with relevant areas of expertise

In order to obtain specific information concerning the five coastal hazards, specialists were interviewed. Based on a face-to-face interview, two historians, a tsunami expert, a MEPA officer, a meteorologist and an architect were consulted. These interviews were carried out in a semi-structured manner. Indeed, this approach permitted the interviewer to gather additional relevant information while allowing the respondent to elaborate more on the topic at hand. Each interviewee provided sufficient information to enable the researcher to put together the checklist criteria to determine the level of vulnerability along the Gozitan coastal zone. Other relevant data were also recorded to be used where and when it would be necessary.

4.2.1.3 Vulnerability scoring criteria

In determining the level of vulnerability that the coast of Gozo is expected to experience, the researcher identified a number of vulnerability scoring criteria. The rationale underpinning this vulnerability assessment is to develop a coastal risk map for each of the five coastal hazards under study: tsunami, sea level rise, storm surge, flooding and landslide. In turn, by overlaying all the five risk maps representing different critical zones, one can understand and identify the areas that are most vulnerable along Gozo’s coastal zone. In this regard, it is very important to point out that each risk map was validated by experts in the field for accurate reflection.

In this respect, a scale ranging from 5 (very high vulnerability) to 1 (very low vulnerability) was put in place for tsunami and landslide to indicate each area that is vulnerable to both hazards. With reference to a risk scale obtained from UNEP (1998), the two coastal hazards (Table 4.2) are classified into catastrophic, very serious, serious, limited and unimportant. Moreover, due to the limited contours available to accurately map some coastal hazards for sea level rise, flooding and storm surge, a scale of 1 (very low vulnerability), 3 (medium vulnerability) and 5 (very high vulnerability) was adopted (Table 4.3).
Table 4.2

Tsunami and Landslide Classification Scales

<table>
<thead>
<tr>
<th>Scale</th>
<th>Classification</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Catastrophic</td>
<td>Hazard considered as potentially very high which can lead to overwhelming impacts in the coastal zone.</td>
</tr>
<tr>
<td>4</td>
<td>Very serious</td>
<td>Hazard regarded as reasonably high which could pose some threat to coastal assets and human beings.</td>
</tr>
<tr>
<td>3</td>
<td>Serious</td>
<td>The possibility of a coastal hazard occurrence is in evidence and the risk is tolerable. Hence, this scale is the mean between high and low vulnerability.</td>
</tr>
<tr>
<td>2</td>
<td>Limited</td>
<td>Hazard risk is low and there is no call for vigilance.</td>
</tr>
<tr>
<td>1</td>
<td>Unimportant</td>
<td>Impact is relatively minimal or not a hint of the occurrence of coastal hazards</td>
</tr>
</tbody>
</table>

Source: UNEP, 1998

Table 4.3

Sea level Rise, Flooding and Storm Surge Classification Scales

<table>
<thead>
<tr>
<th>Scale</th>
<th>Classification</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>High</td>
<td>Hazard regarded as potentially high which could generate devastating impacts and risk to locals, coastal assets and natural environment.</td>
</tr>
<tr>
<td>3</td>
<td>Medium</td>
<td>Hazard probability is evident. This scale is considered as being in the middle between high and low vulnerability.</td>
</tr>
<tr>
<td>1</td>
<td>Low</td>
<td>Hazard risk is insignificant and the possibility of a coastal hazard occurrence is very low.</td>
</tr>
</tbody>
</table>

Source: Developed by writer

In order to identify the width of the coastal boundary, a terrestrial map at a scale of 1:25000 was used. The entire land area in close proximity to the coastline was cartographically marked using the highest contour line facing the coastal zone as the end point where the vulnerability assessment would be taken place. An altitude of 71m above sea level was taken as the end point regarding the extent of the study area (Figure 4.1). However, not all the hazards under study require the same end points. For tsunami, sea level rise and storm surge, the end point would be relatively close to the coastline where the risk and vulnerability are expected to be the highest. Hence, in this case an altitude of 10m above sea level was used (Figure 4.2).
For each of the assorted coastal hazards under study, different criteria were designed specifically for the island of Gozo to determine the level of vulnerability (Table 4.4). In the case of the present study, long-term risk also plays an important role since this dissertation seeks to identify areas of possible future vulnerability impact.
Calculating tsunami run-up height risk, a conservation of energy flux equation was utilised (Chesley and Ward, 2004). The equation is given by:

\[ R = A^{4/5} h^{1/5} \]

where \( R \) is run-up height, \( A \) is wave amplitude and \( h \) is water depth.

Moreover, to evaluate sea level rise three data points were used. To date in Malta, the current increase is 1cm, while a rise of 0.5m and 1m in 2050 and 2100 respectively is being predicted (MEPA, 2006b). Alternatively, as for the rest of the coastal hazards, different contours above sea level (Table 4.4) are taken into account to assess the risk imposed on the littoral zone.

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Criterion</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsunami</td>
<td>Bathymetry</td>
<td>This refers to the coastal depth surrounding Gozo. Different depths were taken into account, namely 2m, 5m, 10m, 20m, 50m, 100m and 200m below sea level. Depending on the bathymetry depth, tsunami wave energy and height would vary in impact.</td>
</tr>
<tr>
<td></td>
<td>Low-lying coast</td>
<td>This refers to the lowest possible coastal elevation above sea level. Tsunami impact will be low in a sheer cliff zone while high in a low-lying area. Hence, a 10m contour above sea level is applicable to suit this criterion.</td>
</tr>
<tr>
<td></td>
<td>Underwater earthquake sources</td>
<td>The western Hellenic Arc (latitude 35° and longitude 22° from the left bottom of the fault) and Eastern Sicily Plateau (latitude 36.5° and longitude 14.5° from the left bottom of the fault) can both directly affect a large part of the Gozitan coastline at different angles and run-up. Wave amplitudes of 5m (Hellenic Arc) and 0.5m (Eastern Sicily Plateau) are considered.</td>
</tr>
<tr>
<td></td>
<td>Anthropogenic land-cover</td>
<td>Anthropogenic assets in close proximity to the coastline are all taken into consideration. In fact, an estimate of 50% of urban coastal land-cover is located within 10m above sea level. Residential units, recreational areas (restaurants, bars), infrastructure development (roads, coastal embellishments) and industrial zones (harbour, yacht marina) are amongst the anthropogenic land-cover.</td>
</tr>
<tr>
<td>Sea level rise</td>
<td>Coastal landforms</td>
<td>This criterion refers to all the natural coastal landforms that are more vulnerable to and at risk from such a hazard. Pocket beaches, shore platforms and coastal inlets are directly affected by rising sea level.</td>
</tr>
<tr>
<td>Category</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Low-lying coast</td>
<td>Since the contour lines obtained are of a 10m interval, data below 10m is not available. Hence, a 10m contour line is used to represent low-lying coasts.</td>
<td></td>
</tr>
<tr>
<td>Coastal infrastructure</td>
<td>This criterion covers all the coastal infrastructural developments such as roads, coastal embellishments, and medium-rise buildings, among others at risk by rises in sea levels.</td>
<td></td>
</tr>
<tr>
<td>Storm surge</td>
<td>Low-lying coast: Similar to tsunamis and sea level rise, a 10m range above sea level will be taken into account for low-lying coasts. Storm surges usually occur in winter and take place for a longer time. Hence, settlements and other assets located at the coastal front will receive the first impact. In particular, ground floor buildings and recreational zones are at higher risk.</td>
<td></td>
</tr>
<tr>
<td>Coastal infrastructure</td>
<td>Storm surges usually occur in winter and take place for a longer time. Hence, settlements and other assets located at the coastal front will receive the first impact. In particular, ground floor buildings and recreational zones are at higher risk.</td>
<td></td>
</tr>
<tr>
<td>Flooding</td>
<td>Valley systems: Gozo has several valley systems that all lead to coastal zones. After intense rainy periods low lying coastlines (10m above sea level) and joining valley channels are the most impacted by flooding phenomena. Areas above 30m above sea level usually suffer minimal impact. Catchment/ watershed areas: This criterion refers to all those drainage basins that flow from high ground and escarpments towards the coast via runoff conduits. A 70m above sea level contour line will be considered as the highest altitude of the study area.</td>
<td></td>
</tr>
<tr>
<td>Landslide</td>
<td>Stratigraphy: Geological strata, namely Blue Clay and Quaternary deposits are taken into consideration especially to the North and East of Gozo. Contour lines between 50-70m above sea level are considered applicable to suit this criterion. Escarpments, clay slopes, and boulder fields suffer the highest impact whereas stabilised areas experience low impact.</td>
<td></td>
</tr>
</tbody>
</table>

Source: Developed by writer

4.2.2 Secondary Data Techniques

As part of the research, various publications and other literature were consulted including academic books, journals, papers and articles which provided useful information on this subject. Additionally, an analysis of several maps of Gozo, obtained from MEPA, Malta Resource Authority and Google Earth was carried out. Such maps included aerial photography, geological maps, contour maps, survey sheets and terrestrial maps. Finally, the national archives was also consulted in the search for past coastal vulnerability events on the Gozitan coastal zone.
4.3 METHODS OF DATA INVESTIGATION

4.3.1 GIS – Geographic Information Systems

One unique difference between digital maps and conventional paper maps is the fact that digital maps display data, which is stored in a database, which permits the user to manipulate the raw data (Hendricks, 2003). For this purpose, a Geographic Information System is best suited to this dissertation. Allowing the user to store both spatial and temporal data (Raju, n.d.), a GIS is used to capture, create, store, analyse, manipulate and display geographical information (Punimia et al., 2006).

Through the use of GIS, several maps superimposing the areas of high and low risk were generated. Different attribute data sets were taken into account for all of the five coastal hazards, each considered as vital for the creation of a coastal risk map. Such attributes included valley systems, beaches, landscape units, low-lying areas and administrative units. Hence, the three main data types, namely points, lines and polygons were used to map the Gozitan coastal zone, particularly for polygons and lines as these modelled risk zones and contours respectively.

Each category of attribute data was needed for the compilation of various data layers including contour and bathymetry depth layers, settlements, land use layers and several geo-referencing layers. By overlaying different data layers, each of which contains applicable information for all the five hazards, the researcher facilitated the identification of the major areas at high risk. Appropriate shades of colour were used to help the reader to visually identify such risk zones.

4.3.2 SPSS – Statistical Package for the Social Sciences

The Statistical Package for the Social Sciences (SPSS) is a statistical analysis software package used to conduct quantitative data analysis (Muijs, 2004). It provides a set of features for the user to manipulate, analyse and present data results in a graphical format (Morrison, 1999). In this research such a programme was employed to analyse the data obtained from the 150 questionnaires. Cross tabulation and Pearson Chi-Square test
were mainly used. These two techniques are both appropriate methods to analyse and interpret the data at hand.

Simple to conduct, cross tabulation is a table showing the number of cases falling into the categories of two variables selected for analysis (Muijs, 2004). Such a technique allows the user to explore for patterns of interactions by interrelating two different variables with each other (Wagner, 2007). On the other hand, the Pearson Chi-Square test is used to verify whether there is a relationship amongst two definite variables (Morgan and Griego, 1998), thus explaining the null and alternative hypotheses:

- **H₀** – the categories in the two variables are independent and have no association between each other (null hypothesis).
- **H₁** – There is a significant association between the two categorical variables implying that the proportions vary considerably between the two variables (alternative hypothesis).

As Dupont (2002) explained, the P-value is the criterion to determine whether to accept H₀ or H₁. Thus, if the P-value exceeds the 0.05 level of significance the null hypothesis is not rejected, otherwise the null hypothesis is rejected and the alternative hypothesis is statistically significant (with 95% confidence).

### 4.3.3 Visual Analysis Techniques

Due to physical limitations, 74% of Gozo’s coastline is defined as inaccessible from land (Axiak, 1992). Nevertheless, since a substantial part of this dissertation entails mapping the coast of Gozo in search of coastal vulnerability areas, a visual analysis of several aerial photographs taken in 2004 was carried out. Such photography aims to facilitate the mapping of various inaccessible zones that are of crucial importance for this research.

Moreover georeferencing Google Earth images facilitated the GIS mapping process. Thus, overlying these images on other data layers further increases the level of accuracy and precision. During the field study, a terrestrial map and a base map obtained from MEPA were used to provide a clear idea of the coastal boundary under study and also to map the areas vulnerable to the five hazards.
4.4 CONSTRAINTS ENCOUNTERED

Throughout this study, several limitations and problems were encountered. In particular, during the field study, lack of access to the entire Gozitan coastal zone on a number of occasions made it difficult to assess the level of vulnerability to the five coastal hazards. In some instances, mapping had to be done using aerial photography. Moreover, precision in the GIS mapping process presented some other difficulties. Since some coastal areas had to be mapped using Google Earth and aerial photography, it was difficult to accurately map the location of specific factors.

Another constraint encountered was the lack of cooperation in the distribution of questionnaires amongst the local people. Although the questionnaire was to take the form of a face-to-face interview to ensure that the respondents easily understood the questions asked, some locals were reluctant to cooperate. Some argued that this questionnaire was to serve for a new MEPA policy, while others were simply not interested in participating. Furthermore, as for the interviews conducted amongst the specialists/professionals, not all of the interviewees cooperated in setting up an appointment to be interviewed. Some simply did not respond to the researcher’s request.
Chapter 5

INTERPRETATION OF RESULTS AND ANALYSIS

5.1 CHAPTER OUTLINE

This chapter describes all the results and analyses obtained from the primary data techniques described in Chapter 4. In order to understand the extent of vulnerability the Gozitan coastal zone is expected to encounter, a thorough evaluation of five risk maps was carried out. The main coastal geographical locations, mentioned in this chapter are depicted in Figure 5.1 Moreover, various techniques were used to analyse and interpret the level of preparedness and awareness that locals have towards the five coastal hazards under study.
5.2 INTERPRETATION OF VULNERABILITY MAPS

From the available data provided by the competent authorities, the vulnerability for each of the five coastal hazards (i.e. tsunami, sea level rise, flooding, landslide and storm surge) was evaluated to produce five risk maps indicating areas of high and low vulnerability on Gozo. Since one of the main objectives of this dissertation is to identify the extent to which each of these hazards presents a threat to Gozitan society, the following points were taken into consideration in the evaluation of each coastal hazard:

- Population (population density and demographic characteristics specifically, identifying vulnerable groups such as children and senior citizens),
- Location of coastal settlements,
- Location of infrastructure (roads, promenades and coastal embellishments),
- Economic factors.

5.2.1 Risk Map Evaluations

5.2.1.1 Tsunami risk on the island of Gozo

The eastern Sicily Plateau and the western Hellenic Arc were taken into account as the two underwater seismic sources which could potentially generate a tsunami affecting the Maltese Islands.

The tsunami waves originating from the two zones would approach Gozo at different rates and in different directions. In this respect, the arrival time for a tsunami generated in eastern Sicily (Figure 5.2) is approximately 50 minutes with the maximum wave amplitude at 0.5m (Raungrassamee and Intavee, 2008). On the other hand, the estimated arrival time for a tsunami generated in the western Hellenic Arc (Figure 5.3) is 90 minutes with wave amplitude of 5m (Raungrassamee and Intavee, 2008). Thus, due to its intensity and magnitude, a western Hellenic Arc tsunami is likely to cause the most severe damage and run-up to the coastal zone.
Evaluating the tsunami risk map (Figure 5.4) on Gozo, one can note that there are several areas at high risk. Due to the fact that wave height varies with sea depth, the tsunami wave reaching areas at a 2m bathymetry level will produce higher waves than areas at 10m bathymetry level. Consequently, certain areas are at higher risk than others. Ir-Ramla, San Blas and Mgarr Harbour are amongst these high risk zones, together with Marsalforn and Hondoq ir-Rummien. The Xlendi area is shown to have lower vulnerability, notwithstanding the fact that there are historical records indicating the occurrence of a tsunami in this area (Camilleri, 2003). It would thus appear that this historical event was caused by other seismic sources.
Population density in the coastal zone varies according to seasons. A tsunami occurring in mid-winter would not affect as many people _per se_ since most of the people would be in inland areas. However, in the peak summer months, coastal zones witness a dramatic increase in population flow, especially in these areas considered to be at high risk. Most often, the first few meters from the coastline are the most densely populated. Ir-Ramla and Marsalforn are highly frequented by tourists and locals that stay in the area in the summer months, to stroll on the promenade area, swim or dine in several restaurants. Hence, a tsunami occurrence at this time is bound to result in several unexpected consequences. However, on a positive note, since both tsunamis are of distant origins, this would give authorities more time to evacuate the threatened coastal area. This is dependent, however, on accurate and timely tsunami forecasts and effective contingency planning.

In high risk zones, moveable objects such as vehicles, sea craft equipment, boats and coastal furnishing such as deckchairs, benches, tables and chairs can cause injury to persons, damage to buildings or even block evacuation routes. Marsalforn, Mgarr Harbour and ir-Ramla are areas where moveable objects can be located, especially during summer months. In fact, as argued by Papathoma _et al._ (2003) a three-meter run-up wave managed to move an iron container weighing one ton, a distance of five meters in the Gulf of Corinth, Greece.

Socio-economic aspects in high risk zones can suffer both direct and indirect damage from a tsunami. Both assets (direct losses) and the flow of the production of services and goods (indirect damages) would be severely impacted (UN-SPIDER, 2010). In Mgarr Harbour, despite the fact that run-up is expected to be much higher due to the tsunami waves approaching from the western Hellenic Arc, this zone provides a crucial link to mainland Malta and is thus disproportionately vulnerable. It also hosts several features including a yacht marina, a fishing port, an industrial zone for the large vessels to transport merchandise, a new ferry terminal, and several businesses including bars and restaurants. On impact many of these assets would be severely damaged. Additionally, in high risk areas medium-rise buildings along the coastal promenade of Marsalforn would be adversely affected. Such an occurrence is likely to cause much damage and expenses.
Significant loss of income would follow a tsunami occurrence. One third of Malta’s GDP is generated by the tourist industry. With the anticipated damage on tourist attraction sites especially those located in high risk zones, a tsunami would have a dramatic consequence on the local economy. Furthermore, the seafront promenade is considered to be the hub of the major economic activities in Marsalforn. To accommodate both restaurants and holiday apartments on the promenade itself, the ground floor is reserved for restaurants while the other storeys are used for apartments. The same goes for other coastal zones that are at high risk.

Agricultural land could also be exposed to tsunami damage, such as tracts in the vicinity of ir-Ramla and San Blas. In fact, apart from having agricultural land covered up with debris, such areas would be impacted by an increase in the salinity level in the top soil layer. Moreover, erosion is also a major concern. As argued by Camilleri (2006), erosion of bays and sandy beaches could remove up to two meters of sediment. Ir-Ramla, in particular, would be negatively affected due to these erosion processes, especially the sand dune formations, which are of high ecological value. In fact, decreasing beach sediment would directly affect the formation of such dunes.
5.2.1.2 *Sea level rise risk on the island of Gozo*

Considered as a progressive hazard, rising sea level has the potential of causing indirect consequences and negative impacts. Coasts and low lying areas are the most exposed to the increasing risk of rising sea level. Hence, this impact will be exacerbated by increasing human-induced pressures on coastal regions. Sea level rise figures and statistics vary from one publication to another (Formosa and Bartolo, 2008). To date, the acknowledged increase in sea level rise in Malta is by 1cm while the projected increase is 0.5m by 2050 and 1m by 2100 (MEPA, 2006b).

When the sea level rise risk map on the island of Gozo (Figure 5.5) is appraised, significant changes in the coastal landscape are expected. A large part of the coastal area will become submerged. In fact, in areas of high risk, conflict of interest between stakeholders for space along the coastal boundary can have several repercussions. Apart from reduction in the land size, this gradual rise in sea level could have a negative effect on coastal populations, settlements, infrastructure, the natural environment and the local economy. Indeed, ir-Ramla, Marsalforn, Xlendi, Dwejra and Mgarr Harbour are areas mostly at high risk as socio-economic assets would be affected.

The elimination of several recreational zones would have a negative impact on the local community. During peak summer months Gozo experiences high population levels in coastal areas; the confined space due to rising sea level could thus result in multiple negative consequences. More land area could be exploited to accommodate all inhabitants that visit such regions. In ir-Ramla, rising sea level implies that more land further inland could be occupied. The resultant unintended consequence would be degradation of the protected sand dunes. Similarly, in the coastal front of the Xlendi and Marsalforn regions, coastal development and recreational zones might be shifted to higher elevations. The outcome would be the transformation of more agricultural fields into built-up regions.

Unfortunately, due to sea level rise, the high probability of losing some of the beaches around the island of Gozo is a matter of major concern. In this respect, the small shingle beaches located in Marsalforn and Xlendi would be inundated with seawater whereas other areas including San Blas and Hondoq ir-Rummien would experience reduction in
beach size. It is very important to keep in mind that around the Maltese Islands, only 2.5% of the coastline constitutes sandy beaches (European Commission, 2009). Hence, the beach at ir-Ramla may experience greater concentrations of visitors, as other beach resources are lost. Additionally, several salt pans of various sizes located beneath Xlendi tower, would be inundated by rising sea level. Although nowadays these salt pans are not being used, this site has become a popular area amongst tourists.

Coastal infrastructure and property could also be negatively affected. For instance by 2050, in the limits of Marsalforn, a concrete platform would be inundated with seawater and several streets in high risk areas especially in Xlendi might also become submerged. Other threats can be witnessed in Mgarr Harbour, Mgarr ix-Xini and Dwejra. Some of the boathouses located in the inland sea in Dwejra could suffer adverse consequences and the Mgarr Harbour marina could become inundated. Limited space for fishermen could become a major problem. In addition ground floor buildings would surely be inundated by 2100 in areas such as the Marsalforn seafront. Consequently, the sewage system in this area might be affected, resulting in sewage leakages.

Economic activities would also be influenced. A hotel, several bars and restaurants located in an area known as il-Menqa in Marsalforn and other areas in the limits of Xlendi and Mgarr Harbour are likely to be threatened by sea level rise. Due to this hazard phenomenon, employees might lose their job as the possibility for such bistros to close down is relatively high. Land areas located at higher elevations would be needed for such catering outlets to reopen again. Consequently, more built-up zones would be created in these coastal areas.

The submergence of shore platforms and saltwater intrusion in the groundwater aquifers are other consequences for the natural landscape and environment resulting from sea level rise. Several shore platforms located in ix-Xatt l-Ahmar, Mgarr ix-Xini and in the confines of Hondoq ir-Rummien and Dahlet Qorrot could become inundated with seawater. In fact, in ix-Xatt l-Ahmar, a small islet would form by 2100 as a result of sea level rise. The groundwater aquifers could be adversely affected as saltwater intrusion could directly affect the mean sea level aquifers.
Figure 5.5
SEA LEVEL RISE RISK MAP

Legend

Gozo Region

Sea level rise risk
Risk
5
3
1

SLR Contours 25000
Contour
9
10
5.2.1.3 Flooding risk on the island of Gozo

Flash floods are common occurrences in Malta and are regarded as a major hazard (Briguglio et al., 2006). In fact, flooding phenomena (European Commission, 2009: 2) ...

*seem to be getting worse, particularly in heavily populated areas where the high degree of urbanisation hampers the absorption of water.*

Since Gozo is characterised by several natural watercourses and valley systems, flooding events mostly occur when valley systems do not have the capacity to convey excess water or the accumulation of surface runoff.

Viewing the flooding risk map (Figure 5.6) one can note that low-lying coastlines are most vulnerable. In a recent flooding event, Xlendi is amongst other coastal areas that were negatively affected. As quoted …*roads were turned into rivers in low lying areas whereby the downpour …flooded shops and homes in Xlendi* (Times of Malta, 2010a). This demonstrates the high impact low lying coastlines are facing. In other instances, flooding in joining valley systems is exacerbated due to the excessive water coming from both channels. Marsalforn, ir-Ramla and Xlendi areas are the most dominant high risk sites, together with Mgarr Harbour, Mgarr ix-Xini and Qbajjar.

Anticipated high risk of flooding in Gozo encompasses a wide range of harmful effects on the local population, their belongings, public infrastructure, cultural heritage, industrial production, the natural environment and the economy. On average, although flooding happens in winter months when population levels are commonly low in coastal zones, in Xlendi and Marsalforn many locals still inhabit these areas as their permanent homes. Hence, high risk of flooding could pose a negative threat to the local community. Immediate health impacts could be a major concern since sewage leaching from cesspits as a result of flooding can contaminate the coastal waters and have repercussions on the health of the coastal community.

In spite of the fact that only a few fatalities have been recorded as a result of flooding in the past decades (Inguanez, 2000), locals, living in high risk regions, suffer from other factors. Ground floor buildings for instance, are at high risk for damage. The same applies to major roads which could become inaccessible to the public due to high concentration of mud, removal of road surface, broken tree trunks and other rubble. In
case of an evacuation from such high risk zones, senior citizens or persons with special needs would find it much more difficult as a result of high debris in roads.

Public infrastructure in high risk regions especially in Xlendi and Marsalforn can also be affected negatively. The removal of pavements, coastal promenades, signs, benches and other ornaments can occur with flood water. Past events show that a large percentage of this public infrastructure ends up at sea.

Economic factors are also highly vulnerable. High risk areas could see an impact on the catering sector with resultant loss of employment. Popular bars and restaurants in Marsalforn and Xlendi could be damaged as a result of flooding in ground floors. Appliances, cooking equipment and furniture could become unusable, thus preventing locals and tourist from dining in these areas. Moreover, the high risk area in Mgarr Harbour is daily frequented by fishermen. Apart from congestion and damage to fishing vessels and equipment, flooding could hinder the fishermen in accomplishing their work. Sewage pipes in high risk zones can be damaged, thus causing obnoxious smells, discouraging visitors from these areas.

Although in ir-Ramla, San Blas and Dahlet Qorrot the local population is not affected by flooding, other impacts could be generated. In fact, the agricultural sector could be negatively affected. Since most of the agricultural fields in these high risk regions are located on sloping ground, the risk of soil erosion especially on bare soil is very high. Furthermore, soil contamination and waterlogging could be exacerbated in such zones. Since most of the runoff comes directly from high escarpment and urban areas, water contamination by various pollutants can ruin and contaminate the agricultural fields and waterlogging could decrease agricultural productivity.

In ir-Ramla, large volumes of beach sediment could be carried out to sea by flood waters, creating a thick channel at the mouth of the valley. This would prevent locals from accessing the entire beach front. Additionally, the freshwater pool situated in the high risk region of Dwejra could be affected with high nitrate levels as a result of sewage leakages from urban areas due to flooding. Eutrophication could result from this impact.
5.2.1.4  Landslide risk on the island of Gozo

Landslide risk is a common phenomenon on Gozo, especially in areas to the north, south-east and east. Landslide can occur depending on the gradient of the slope, erosion processes, and geological strata (presence of Blue Clay and Quaternary deposits). In this research, stabilised escarpment zones are assumed to possess the lowest risk, as is exposure to UCL and LCL, especially to the west and south of Gozo, so landslide risk is low. When this landslide risk map (Figure 5.7), is appraised, it is observed that high risk zones increase along the coastal areas especially where boulder scree, high escarpments and blue clay slopes are present. Indeed, several areas in the vicinity of ir-Ramla, San Blas, Mgarr Harbour and Marsalforn are the most vulnerable areas. The high risk of landslides in such regions could pose a negative threat to coastal settlements, assets, populations, the economy and the natural environment itself.

High vulnerability and risk areas from landslides could have a direct effect on coastal settlements and the local inhabitants. On Gozo, although landslides occur less frequently in the vicinity of coastal settlements, but have a higher incidence in areas inaccessible from land, the probability of occurrence close to coastal settlement exists. Indeed, an unexpected landslide occurrence could have devastating impacts on property, infrastructure and vehicles. As portrayed in section 5.3.1.4, the result of the survey shows that out of all the coastal hazards, the majority of respondents were rather unsure as to whether they were vulnerable to landslides or not. This shows the lack of awareness of the consequences and threat imposed by landslides. Admittedly in Malta, no casualties have been recorded in the past decades (Inguez, 2000). However, beneath the high risk area in Marsalforn there is a popular bathing area which is highly frequented by tourists and locals in the summer months. As a result of slope failure in this area, fatalities may occur.

Interestingly, landslides frequently occur in combination with other events such as flooding (Papathoma-Kohle et al., 2007). During an emergency or evacuation situation from a flooding event in Marsalforn, roads and lines of communications could easily get blocked by rubble and debris due to a landslide occurrence. Such a scenario would prevent locals from getting to safer areas. In other instances, high risk areas in San Blas
and Dahlet Qorrot can also experience blockage in roads and paths from landslides. Indeed, farmers would find it rather difficult to access their fields using machinery.

Landslides can also pose a significant threat to the local economy. In areas where landslide risk is high particularly in Marsalforn and Mgarr Harbour, property value could be reduced and landslides could also cause severe damage to buildings on impact. A case in point is Fort Chambray situated in the limits of Mgarr Harbour, which is being transformed into a holiday complex, hosting several first class apartments. The risk of landslides would surely dampen prospective buyers’ interest in buying property there. Similarly, the proposed development site situated in a high risk zone in ir-Ramla would potentially experience impacts on sales due to the fear of landslide phenomena. Finally, a landslide could potentially damage a well known restaurant situated on top of a high risk area in Mgarr Harbour and may cause fatalities.

Other impacts from high risk areas include several storage rooms used by local farmers, foot paths and boat houses in the confines of ir-Ramla and Dahlet Qorrot. A landslide occurrence would damage and/or destroy such features. Despite the fact that access to agricultural fields would be lost as a result of the accumulation of rubble material, both fishermen and farmers would potentially lose useful assets including farming machinery and sea vessels. Similarly, in Mgarr Harbour, apart from vehicles, private boats and fishing equipment that are stored onshore could suffer severe damage from several boulders that could slide down within this region. Furthermore, a small house, also situated in a high risk area in ir-Ramla, could be badly damaged. Apart from loss of property, casualties could also occur.

The natural environment is amongst the highest at risk from landslides. As a result of several agricultural land areas situated in several high risk regions especially between San Blas and Dahlet Qorrot and between ir-Ramla and Marsalforn, landslide risk could undermine agricultural productivity and agricultural land area. Fertile soils could be lost as a result of landslide risk. Additionally, the Qortin dump site located in the limits of Ghajn Barrani could cause other consequences on the environment. Since it is situated on top of a high risk area for landslide occurrence, there is a risk of pollution of the area. Apart from ruining this coastal landscape, leaching could contaminate the surrounding grounds.
5.2.1.5 Storm surge risk on the island of Gozo

The incidence of storm surges is rather high on the Maltese Islands. These surges pose direct impacts on coastal areas. When compared to the rest of the coastal hazards under study, the probability of occurrence for the other four hazards runs throughout the year whereas storm surges occur only in winter months. Hence, the risk of coastal damage is restricted to a short time frame.

The risk from storm surge hazard would be expected to be relatively higher in regions where anthropogenic assets are located. In fact, coastal infrastructure, and property and high economic areas are prevalent in these high risk zones. Coastal land configuration makes a difference in terms of wave impact on the coastal area. In this respect, in open space zones (Ir-Ramla), the effect of waves would be dissipated and the impact would be lower than in areas known to be enclosed (Xlendi inlet).

When one views the storm surge risk map (Figure 5.8), one can note that the highest risk regions are located in the areas of Marsalforn, Mgarr Harbour and Xlendi followed by medium risk areas such as ir-Ramla San Blas and Hondoq ir-Rummien. Regardless of the fact that coastal populations are not physically harmed, direct damage to coastal infrastructure is high. Indeed, coastal promenades, streets, ground floor units, coastal ornaments and pavements overlooking the sea front in Xlendi could be severely damaged and/or destroyed by wave impact. The coastal landscape could be extensively harmed. Likewise, in several zones within the limits of Marsalforn, storm surges can cause similar damages to Xlendi.

The damage to fishing boats in both Mgarr Harbour and Marsalforn from storm surges can impact the local economy. Apart from the fact that fishing vessels can be severely damaged as has happened in past events when such craft were wrecked on the rocks (Times of Malta, 1967), fishermen could lose their jobs. Other economic consequences of storm surges include the damage to bars and restaurants located in ground floor areas in Marsalforn and Xlendi. In this regard, property damage from storm waves can result when front doors could be forced open as a result of the wave pressure. Moreover, customers might avoid such high risk areas in winter, thus causing loss of revenue to caterers.
Environmental damage from storm surges can pose a threat to medium risk regions such as ir-Ramla and San Blas. Since both coastal zones comprise fine sandy sediment rather than shingle or pebble sediments, the risk of carving out sediment in the backshore region is of major concern. Due to this impact, reducing the volume of sediment could result in a reduction in beach size.
5.2.2 Summary of Major Risk Zones

The coast of Gozo appears to be at major risk to different coastal hazards. A representation of the major areas at risk to the five coastal hazards under study is visually represented through a graduated symbol map (Figure 5.9). In this regard, Mgarr Harbour appears to be the most vulnerable to all the five coastal hazards, followed by coastal areas such as Marsalforn and ir-Ramla which seem to be at high risk to four hazards. It is also interesting to point out that major coastal development works are carried out in these coastal regions.

Additionally, Xlendi and San Blas appear to be the most vulnerable to three coastal hazards while Dwejra, Mgarr ix-Xini and Xatt l-Ahmar seem to be vulnerable to two coastal hazards. Finally, the rest of the coastal areas vulnerable to one particular hazard are Dahlet Qorrot and Hondoq ir-Rummien.

Figure 5.9
Representation of High Risk Coastal Regions
5.3 INTERPRETATION OF QUESTIONNAIRES

In this section, the most important results of the survey on risk perception and participation amongst Gozitan respondents are analysed and discussed. In total 150 questionnaires were distributed with 16 closed-ended questions.

5.3.1 Presentation of Main Results

5.3.1.1 Gender bias

It is quite evident from the following that male respondents appear to be more familiar with most of the terms when compared to female respondents. Indeed, 60.7% of all the views came from male respondents. A Chi-square test was used to test for an association between gender and familiarity of terms. Since the P-value of 0.963 exceeds the 0.05 level of significance one can note that there is no association between these two categorical variables. Hence, there is no gender bias amongst the respondents regarding familiarity of terms.

As shown in Table 5.1, the majority of respondents were most familiar with flooding (26.9%), followed by familiarity with tsunami (24.2%), sea level rise (21.1%), landslide (17.3%) and storm surge (10.6%). Moreover, both males and females showed least familiarity with storm surge while both males and females were most familiar with flooding. However, overall awareness of all of these hazards was low.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>61</td>
<td>24.1%</td>
</tr>
<tr>
<td>Female</td>
<td>40</td>
<td>24.4%</td>
</tr>
<tr>
<td>Total</td>
<td>101</td>
<td>24.2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tsunami</th>
<th>Sea level rise</th>
<th>Storm surge</th>
<th>Landslide</th>
<th>Flooding</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>51</td>
<td>27</td>
<td>46</td>
<td>68</td>
<td>253</td>
</tr>
<tr>
<td>Percentage</td>
<td>20.2%</td>
<td>10.7%</td>
<td>18.2%</td>
<td>26.9%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Female</td>
<td>37</td>
<td>17</td>
<td>26</td>
<td>44</td>
<td>164</td>
</tr>
<tr>
<td>Percentage</td>
<td>22.6%</td>
<td>10.4%</td>
<td>15.9%</td>
<td>26.8%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Total</td>
<td>88</td>
<td>44</td>
<td>72</td>
<td>112</td>
<td>417</td>
</tr>
<tr>
<td>Percentage</td>
<td>21.1%</td>
<td>10.6%</td>
<td>17.3%</td>
<td>26.9%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Table 5.1
Gender Bias
5.3.1.2 *Age categories and familiarity of terms*

Different trends in terms of familiarity of terms can be observed with age groups. According to the Chi-square test, these were, however, found not to be statistically significant since the P-value of 0.813 exceeds the 0.05 level of significance. Hence, the null hypothesis is not rejected, i.e. there is no association between age groups and familiarity of terms.

At first glance, one can note a trend where the higher the age group, the lower the familiarity in terms. Table 5.2, showed that age group 15-30 followed by age group 30-45 were the most familiar with these five coastal hazards especially tsunami and flooding while the age group 60+ seemed to be the least familiar with all the hazard terms (4.1%).

<table>
<thead>
<tr>
<th>Which of the following coastal hazard terms are you familiar with?</th>
<th>Age</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsunami</td>
<td>15-30</td>
<td>30-45</td>
</tr>
<tr>
<td>Count</td>
<td>55</td>
<td>34</td>
</tr>
<tr>
<td>Percentage</td>
<td>54.5%</td>
<td>33.7%</td>
</tr>
<tr>
<td>Sea level rise</td>
<td>15-30</td>
<td>30-45</td>
</tr>
<tr>
<td>Count</td>
<td>51</td>
<td>25</td>
</tr>
<tr>
<td>Percentage</td>
<td>58.0%</td>
<td>28.4%</td>
</tr>
<tr>
<td>Storm surge</td>
<td>15-30</td>
<td>30-45</td>
</tr>
<tr>
<td>Count</td>
<td>19</td>
<td>16</td>
</tr>
<tr>
<td>Percentage</td>
<td>43.2%</td>
<td>36.4%</td>
</tr>
<tr>
<td>Landslide</td>
<td>15-30</td>
<td>30-45</td>
</tr>
<tr>
<td>Count</td>
<td>33</td>
<td>27</td>
</tr>
<tr>
<td>Percentage</td>
<td>45.8%</td>
<td>37.5%</td>
</tr>
<tr>
<td>Flooding</td>
<td>15-30</td>
<td>30-45</td>
</tr>
<tr>
<td>Count</td>
<td>62</td>
<td>33</td>
</tr>
<tr>
<td>Percentage</td>
<td>55.4%</td>
<td>29.5%</td>
</tr>
<tr>
<td>Total</td>
<td>220</td>
<td>135</td>
</tr>
<tr>
<td>Percentage</td>
<td>52.8%</td>
<td>32.4%</td>
</tr>
</tbody>
</table>

5.3.1.3 *Knowledge obtained from different sources*

Analysis revealed that there was a higher proportion of respondents seeking information about flooding (30.9% respondents), compared to other hazards, with tsunami, sea level rise, landslide and storm surge trailing in rank order. When the Chi-square test is evaluated, there were significant differences relating to the sources of information for all the coastal hazards since the P-value (0.000) is less than the 0.05 level of significance. Hence, the null hypothesis is rejected and the alternative hypothesis is accepted.
On a general note (Table 5.3), it is evident that for all the coastal hazards Internet and other media were the predominant source of information for the respondents while the Civil Protection Department appears to be the least helpful in providing information. From other observations, the respondents acquired specific information on particular hazards from different sources. For instance, the local authorities are the main source of information for tsunami (22.9%), neighbours and friends for sea level rise (27.0%), internet or other media for storm surge (62.3%), civil protection for landslides (12.8%) while schools and education centres seem to provide more information on flooding (17.6%).

Table 5.3
Knowledge Provided from Different Source

<table>
<thead>
<tr>
<th>Coastal hazards</th>
<th>From where have you learnt about coastal hazards?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Local authorities</td>
</tr>
<tr>
<td>Tsunami</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td>36</td>
</tr>
<tr>
<td>Sea level rise</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td>19</td>
</tr>
<tr>
<td>Storm surge</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Landslide</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td>11</td>
</tr>
<tr>
<td>Flooding</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td>29</td>
</tr>
<tr>
<td>Total</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td>103</td>
</tr>
</tbody>
</table>

5.3.1.4 Vulnerability to any coastal hazards

Respondents were asked whether they considered themselves vulnerable to any of the five coastal hazards. The majority of respondents considered themselves more vulnerable to particular hazards since they were more likely to experience certain hazards when compared to others. A Chi-square test was generated for this particular association. Since the P-value (0.000) is smaller than 0.05 level of significance, the alternative hypothesis is accepted. Therefore, an association can be claimed between respondent’s perceived vulnerability and coastal hazards.
At first glance (Table 5.4), a high proportion of the respondents (41.9%) consider themselves not vulnerable to any of the five coastal hazards. Those respondents who were unsure or else consider themselves vulnerable to coastal hazards amounted to 23.7% and 34.4% respondents respectively.

<table>
<thead>
<tr>
<th>Coastal Hazards</th>
<th>Do you consider yourself vulnerable to any of the five coastal hazards?</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Tsunami</td>
<td>38</td>
<td>80</td>
</tr>
<tr>
<td>Percentage</td>
<td>25.3%</td>
<td>53.3%</td>
</tr>
<tr>
<td>Sea level rise</td>
<td>71</td>
<td>54</td>
</tr>
<tr>
<td>Percentage</td>
<td>47.3%</td>
<td>36.0%</td>
</tr>
<tr>
<td>Storm surge</td>
<td>29</td>
<td>87</td>
</tr>
<tr>
<td>Percentage</td>
<td>19.3%</td>
<td>58.0%</td>
</tr>
<tr>
<td>Landslide</td>
<td>43</td>
<td>52</td>
</tr>
<tr>
<td>Percentage</td>
<td>28.7%</td>
<td>34.7%</td>
</tr>
<tr>
<td>Flooding</td>
<td>77</td>
<td>41</td>
</tr>
<tr>
<td>Percentage</td>
<td>51.3%</td>
<td>27.3%</td>
</tr>
<tr>
<td>Total</td>
<td>258</td>
<td>314</td>
</tr>
<tr>
<td>Percentage</td>
<td>34.4%</td>
<td>41.9%</td>
</tr>
</tbody>
</table>

From the same cross tab, it is clear that respondents perceived themselves as more vulnerable and at risk to certain hazards.

- A high proportion of respondents considered themselves vulnerable to sea level rise (47.3%) and flooding (51.3%);  
- Lowest perceived vulnerability was to tsunami (53.3%) and storm surge (58.0%); whereas  
- The highest level of uncertainty related to the dangers posed by landslide (36.7%) threat.

5.3.1.5 Knowledge level towards the five hazards

A similar pattern was obtained from the respondents regarding their level of knowledge of the five coastal hazards. According to the Chi-square analysis, the alternative hypothesis is accepted since the P-value of 0.000 is smaller than the 0.05 level of significance. Hence, one can deduce that there is a significant association between age and the respondent’s level of knowledge.
According to the results obtained (Table 5.5), 51.3% of the respondents pointed out that they were not informed at all. Undoubtedly, having half of the respondents unknowledgeable about the five hazards is a critical issue.

Table 5.5
Respondents' Level of Knowledge Compared with Age

<table>
<thead>
<tr>
<th>Age</th>
<th>Count</th>
<th>Well informed</th>
<th>Moderately informed</th>
<th>Not informed at all</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-30</td>
<td>6</td>
<td>40</td>
<td>25</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>8.5%</td>
<td>56.3%</td>
<td>35.2%</td>
<td>100.0%</td>
</tr>
<tr>
<td>30-45</td>
<td>6</td>
<td>6</td>
<td>8</td>
<td>36</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>12.0%</td>
<td>16.0%</td>
<td>72.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>45-60</td>
<td>3</td>
<td>9</td>
<td>10</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>13.6%</td>
<td>40.9%</td>
<td>45.5%</td>
<td>100.0%</td>
</tr>
<tr>
<td>60+</td>
<td>1</td>
<td>0</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>14.3%</td>
<td>0%</td>
<td>85.7%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>57</td>
<td>77</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>10.7%</td>
<td>38.0%</td>
<td>51.3%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

The only age category that showed some knowledge of the five coastal hazards is the 15-30 age group who considered themselves moderately informed (56.3%). Moreover, as for the rest of the age groups, their level of knowledge appeared to be quite low since the majority claimed they were not informed at all. None of the age categories claimed to be well informed about coastal hazards. On a positive note, the level of knowledge seems to be increasing amongst the younger age groups.

5.3.1.6 Preparedness and protection amongst respondents

Although from the clustered bar graph (Figure 5.10), male respondents considered themselves to be much more aware of ways to protect themselves, the overall majority of respondents did not know how to act in an emergency situation. The result obtained from the Chi-square test showed that since the P-value of 0.158 is greater than 0.05 level of significance, the null hypothesis (H₀) is not rejected. Thus, we can conclude that there is no relationship between gender and personal protection from the five coastal hazards under study.
Male respondents (12.7%) appeared to have better awareness of how to protect themselves while female respondents (28.7%) claimed to have the least knowledge of what to do in case of a hazardous occurrence. As for the rest of the respondents, although males claimed to be the most knowledgeable about how to protect themselves, it is interesting to note that other male participants claimed to be unsure (14.7%) about personal protection in case of a hazard occurrence.

Moreover, as expected, after examining the relation between two categorical variables (Figure 5.11), one can also note that several respondents argued that they did not know how to protect themselves simply because they did not have prior knowledge about the five coastal hazards under study. This result suggests that most Gozitans have an insufficient level of awareness, preparedness, protection mechanisms and information level. Furthermore, the Chi-squared analysis shows that since the P-value (0.000) is less than 0.05 level of significance, there is an association between respondent’s knowledge level and personal protection. Hence, the alternative hypothesis is accepted.

Those respondents that seemed to be well informed argued that in case of an occurrence of any of the five coastal hazards, they knew ways how to protect themselves (6.7%) whereas those respondents that claimed they were not informed, pointed out that they
did not know how to protect themselves (34.7%). Others who claimed to be moderately informed stated that in case of a coastal hazard occurrence they did not know how to protect themselves (22.0% each).

Out of 150 respondents, only 27 locals knew how to protect themselves (18.0%). Consequently, by extrapolation through simple proportion, only an estimated 5,400 locals (out of 30,000 inhabitants) would be expected to know how to protect themselves in the case of a coastal hazard occurrence.

5.3.1.7 Hazard perceived probability occurrence
Respondents were also asked to express their perceptions of the probability of occurrence for any of the five coastal hazards along the Gozitan littoral zone. According to the Chi-square test, the association is significant and not attributable to chance since the P-value (0.000) is less than the 0.05 level of significance. Hence the alternative hypothesis is accepted since an association can be claimed between the five coastal hazards and perceived probability of occurrence.
As noted in Table 5.6, a high majority of respondents (44.8%) argued that the probability of occurrence was quite low. This result is followed by that of other respondents (30.3%) who pointed out that the probability was medium whereas only some respondents claimed a high probability along the Gozitan coastal zone. Moreover, when each hazard is analysed individually, according to the respondents, the only hazard that is considered likely to occur along the island of Gozo was sea level rise (35.3%). Landslide registered a medium perceived probability of occurrence (41.3%) whereas tsunami (66.0%), storm surge (55.3%) and flooding (38.0%) were noted as the least probable to occur along the Gozitan littoral zone according to the respondents. A contradiction can be observed amongst the respondents, since in Section 5.3.1.4 the respondents considered themselves highly vulnerable to flooding, whereas in this case the perceived probability of occurrence for flooding was low.

<table>
<thead>
<tr>
<th>Coastal hazards</th>
<th>Count</th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsunami</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>22</td>
<td>29</td>
<td>99</td>
<td>150</td>
</tr>
<tr>
<td>Percentage</td>
<td></td>
<td>14.7%</td>
<td>19.3%</td>
<td>66.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Sea level rise</td>
<td></td>
<td>53</td>
<td>51</td>
<td>46</td>
<td>150</td>
</tr>
<tr>
<td>Count</td>
<td></td>
<td>53</td>
<td>51</td>
<td>46</td>
<td>150</td>
</tr>
<tr>
<td>Percentage</td>
<td></td>
<td>35.3%</td>
<td>34.0%</td>
<td>30.7%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Storm surge</td>
<td></td>
<td>22</td>
<td>45</td>
<td>83</td>
<td>150</td>
</tr>
<tr>
<td>Count</td>
<td></td>
<td>22</td>
<td>45</td>
<td>83</td>
<td>150</td>
</tr>
<tr>
<td>Percentage</td>
<td></td>
<td>14.7%</td>
<td>30.0%</td>
<td>55.3%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Landslide</td>
<td></td>
<td>37</td>
<td>62</td>
<td>51</td>
<td>150</td>
</tr>
<tr>
<td>Count</td>
<td></td>
<td>37</td>
<td>62</td>
<td>51</td>
<td>150</td>
</tr>
<tr>
<td>Percentage</td>
<td></td>
<td>24.7%</td>
<td>41.3%</td>
<td>34.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Flooding</td>
<td></td>
<td>53</td>
<td>40</td>
<td>57</td>
<td>150</td>
</tr>
<tr>
<td>Count</td>
<td></td>
<td>53</td>
<td>40</td>
<td>57</td>
<td>150</td>
</tr>
<tr>
<td>Percentage</td>
<td></td>
<td>35.3%</td>
<td>26.7%</td>
<td>38.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>187</td>
<td>227</td>
<td>336</td>
<td>750</td>
</tr>
<tr>
<td>Count</td>
<td></td>
<td>187</td>
<td>227</td>
<td>336</td>
<td>750</td>
</tr>
<tr>
<td>Percentage</td>
<td></td>
<td>24.9%</td>
<td>30.3%</td>
<td>44.8%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

5.3.1.8 Provision of information

A clear distinction can be observed from the response rate. According to Table 5.7, only a third of the respondents (50 out of 150) argued that information was provided by the responsible authorities. The Chi-square analysis generated for this association namely between provision of information and information sources suggests that there is an association since the P-value (0.000) is smaller than 0.05 level of significance.
In fact, private agencies seem to be providing most of this information since some of the respondents pointed out that the information provided was very helpful (6.0%) while others argued that the information was satisfactory (16.0%). Only 2.7% of respondents claimed that the information provided by the local authorities was insufficient. Hardly any respondents noted that government services offered adequate information on coastal hazards. Despite the fact that some respondents argued that a small proportion of information was provided by the responsible authorities, the majority of the respondents (65.3%) argued the opposite. It can be noted that the lack of information offered about coastal hazards to the public is blamed on the fact that there is no service being provided by the competent authorities.

Table 5.7
Provision of Information from Responsible Authorities

| How have you learnt about personal protection in the event of a hazard? | How would you rate the provision of information about coastal hazards by the responsible authorities? |
|---|---|---|---|---|---|
| | Very helpful | Satisfactory | Poor service | No service offered | Total |
| Local authorities | Count | 3 | 2 | 4 | 0 | 9 |
| | Percentage | 2.0% | 1.3% | 2.7% | .0% | 6.0% |
| Government services | Count | 1 | 3 | 1 | 0 | 5 |
| | Percentage | .7% | 2.0% | .7% | .0% | 3.3% |
| Private agencies and NGOs | Count | 9 | 24 | 3 | 0 | 36 |
| | Percentage | 6.0% | 16.0% | 2.0% | .0% | 24.0% |
| No information offered | Count | 0 | 0 | 2 | 98 | 100 |
| | Percentage | .0% | .0% | 1.3% | 65.3% | 66.7% |
| Total | Count | 13 | 29 | 10 | 98 | 150 |
| | Percentage | 8.7% | 19.3% | 6.7% | 65.3% | 100.0% |

5.3.1.9 Factors contributing to coastal vulnerability

This question aims at finding out what the local respondents think about the factors contributing to an increase in coastal vulnerability (Figure 5.12).

Similar patterns were noted amongst several views obtained from the respondents. The predominant reason given by the respondents (22.7%), was that there seemed to be a lack of appropriate mitigation and monitoring schemes. Given that the Gozitan littoral zones are highly frequented by locals and also foreigners especially in the peak summer months, monitoring schemes and suitable mitigation measures should be a top priority.
to lessen coastal vulnerability. Moreover, the respondents argued that inadequacies in legislation (22.0%) could also contribute to coastal vulnerability.

Additionally, a further 19.3% of respondents pointed out that there were insufficient planning and awareness-raising initiatives, followed by 14.0% of respondents who stated that there was a lack of coordination between the stakeholders. Finally the respondents further argued that incomplete availability of coastal data (11.3%) and poor communication systems (10.7%) could also contribute to an increase in coastal vulnerability.

![Figure 5.12 Reasons Contributing to Coastal Vulnerability](image)

5.3.1.10 Ways to reduce coastal vulnerability

Out of all the methods to reduce coastal vulnerability, an increase in education and awareness schemes was the most preferred response by the respondents followed by monitoring the area. According to the Chi-square test, the alternative hypothesis is accepted since the P-value of 0.000 is less than 0.05 level of significance, indicating a significant association between sufficient protective mechanisms and ways to reduce vulnerability.
Table 5.8 shows that 48.0% of the respondents claimed that there were not enough protective mechanisms to protect the Gozitan coastal zones. Others were unsure or else claimed the opposite.

<table>
<thead>
<tr>
<th>What do you suggest to be done to lessen coastal vulnerability?</th>
<th>Are there sufficient protective mechanisms to protect the coast of Gozo in the event of coastal hazards?</th>
<th>Yes</th>
<th>No</th>
<th>Unsure</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Already enough methods of protection</td>
<td>Count</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>6.7%</td>
<td>.0%</td>
<td>.0%</td>
<td>6.7%</td>
</tr>
<tr>
<td>Monitoring the area</td>
<td>Count</td>
<td>3</td>
<td>19</td>
<td>13</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>2.0%</td>
<td>12.7%</td>
<td>8.7%</td>
<td>23.3%</td>
</tr>
<tr>
<td>Introduce new techniques and types of construction</td>
<td>Count</td>
<td>2</td>
<td>25</td>
<td>5</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>1.3%</td>
<td>16.7%</td>
<td>3.3%</td>
<td>21.3%</td>
</tr>
<tr>
<td>Increase in early warning systems</td>
<td>Count</td>
<td>5</td>
<td>3</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>3.3%</td>
<td>2.0%</td>
<td>4.7%</td>
<td>10.0%</td>
</tr>
<tr>
<td>Increase in education and awareness schemes</td>
<td>Count</td>
<td>5</td>
<td>21</td>
<td>19</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>3.3%</td>
<td>14.0%</td>
<td>12.7%</td>
<td>30.0%</td>
</tr>
<tr>
<td>Other</td>
<td>Count</td>
<td>1</td>
<td>4</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>.7%</td>
<td>2.7%</td>
<td>5.3%</td>
<td>8.7%</td>
</tr>
<tr>
<td>Total</td>
<td>Count</td>
<td>26</td>
<td>72</td>
<td>52</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>17.3%</td>
<td>48.0%</td>
<td>34.7%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Moreover, the few respondents that stated that there were adequate mechanisms to safeguard the littoral zone, pointed out that there were enough methods of protection (6.7%). On the other hand, those respondents that claimed the contrary suggested that there should be an increase in monitoring of the coastal zones by the responsible agencies (12.7%), introduction of new techniques and types of construction to overcome any coastal hazards (16.7%), and an increase in education and awareness schemes in schools and in public events (14.0%).

Finally those respondents who claimed to be unsure whether there were sufficient mechanisms to protect the coast argued that there should be an increase in early warning systems (4.7%), whereas 5.3% specified that there were other ways apart from those listed that could in fact minimise coastal vulnerability.

5.3.1.11 Personal involvement in coastal hazard-related events
It is quite obvious from the response rate that public events such as conferences and seminars on coastal hazards were not given top priority when compared with other events on other themes. As the Chi-square analysis suggests, since the P-value of 0.000 is less than 0.05 level of significance, the alternative hypothesis \( (H_1) \) is accepted, indicating a significant association between respondent’s personal involvement and hazard related events.

The majority of the respondents (80.0%) had never participated in a coastal hazard event, stating that they had never encountered any public events about this topic. Only 20.0% of the respondents did take part in a public event pertaining to coastal hazards and/or similar event. In fact, the few respondents (Table 5.9) who took part in a public event concerning coastal hazards and preparedness attended an information event (6.7%). Others (6.0%) attended workshops while another 4.7% of the respondents participated in a conference. Only 2.7% specified that they attended other events apart from those listed in the questionnaire.

Table 5.9
Participation in Coastal Hazard Events

<table>
<thead>
<tr>
<th>What type of event was it?</th>
<th>Have you ever taken part in a public event concerning coastal hazard preparedness, awareness and/or coastal protection?</th>
<th>Yes</th>
<th>No</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workshops</td>
<td>Count</td>
<td>9</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>6.0%</td>
<td>.0%</td>
<td>6.0%</td>
</tr>
<tr>
<td>Information event</td>
<td>Count</td>
<td>10</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>6.7%</td>
<td>.0%</td>
<td>6.7%</td>
</tr>
<tr>
<td>Conference</td>
<td>Count</td>
<td>7</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>4.7%</td>
<td>.0%</td>
<td>4.7%</td>
</tr>
<tr>
<td>Never encountered any public event about this topic</td>
<td>Count</td>
<td>0</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>.0%</td>
<td>80.0%</td>
<td>80.0%</td>
</tr>
<tr>
<td>Other</td>
<td>Count</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>2.7%</td>
<td>.0%</td>
<td>2.7%</td>
</tr>
<tr>
<td>Total</td>
<td>Count</td>
<td>30</td>
<td>120</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>20.0%</td>
<td>80.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

5.3.1.12 Public event participation

The last question aimed at pointing out whether the respondents would be interested in participating in future events about the topic under study. From the result of the Chi-
square test, one can note that since the P-value of 0.182 is greater than 0.05 level of significance, the null hypothesis is not rejected. Thus we deduce that there is no association between gender and participation in future events.

The clustered bar graph (Figure 5.13), reveals that 71.3% of respondents would in fact be interested in participating in various events concerning coastal hazards. The majority of these were males (43.3%) while the rest were female respondents. A small proportion of respondents (28.7%) were not interested in attending and/or participating in events featuring the topic at hand, of which female respondents (14.7%) appeared to be the least interested.

![Figure 5.13](image)

**Figure 5.13**

**Interest in Public Events**

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>80%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>70%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40%</td>
<td>43.3%</td>
<td></td>
</tr>
<tr>
<td>30%</td>
<td>28.0%</td>
<td></td>
</tr>
<tr>
<td>20%</td>
<td>14.0%</td>
<td>14.7%</td>
</tr>
<tr>
<td>10%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Would you be interested in participating in future events concerning coastal hazards?**

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>43.3%</td>
<td>14.0%</td>
</tr>
<tr>
<td>28.0%</td>
<td>14.7%</td>
</tr>
</tbody>
</table>

### 5.3.2 Survey Findings

This research investigated whether local citizens are knowledgeable and prepared to deal with coastal hazards and their consequences. After the results of the public survey were analysed, several conclusions were drawn.
To begin with, it is evident that there is a close relationship between risk perception on coastal hazards and socio-demographic factors. Age seems to have a noticeable influence on risk perception. Despite the fact that older age groups were expected to be much familiar with coastal hazards, the survey showed the opposite. In this regard, younger age groups (namely 15-30) were more knowledgeable and perceived risk more intensely.

It appears that there is room for improvement in terms of awareness and general knowledge on coastal hazards. Although some respondents reported to have some background knowledge on coastal hazards, the majority showed that they were not informed. Referring to Chapter 2, Section 2.5.1, an important measure pointed out by Walker et al., (2007) was the need to increase public understanding and level of knowledge of possible hazards. This is an important step in the attempt to reduce long-term vulnerability on coastal communities. In Gozo, lack of knowledge about coastal hazards could lead to severe consequences since the public would not be aware of the impacts generated by each hazard. In other words, the public is indirectly susceptible and more vulnerable to such natural phenomena.

The Internet appears to be one of the main sources from which the respondents are likely to obtain most of the information on coastal hazards. Despite the fact that civil protection, schools and education centres were expected to be providing the majority of information, this survey showed the contrary. Theoretically, since a large percentage of respondents who participated in this survey were aged between 15 and 30, an expected outcome would be that schools and education centres would be providing most of the hazard knowledge. Moreover, with regards to civil protection, although in 2006 it was announced that public awareness is expected to increase with the help of the International Civil Defence Organisation and an EU public awareness programme (Zammit, 2006), this survey showed that very little knowledge was obtained from the CPD.

Risk perception and preparedness are two important factors since these make people act in specific ways before, during and after a natural disaster take place while they strengthen resilience in a coastal society. However, low levels of either or both variables increases the vulnerability of a coastal zone. A major outcome from this survey is that
preparedness, personal protection and risk perception seemed to be lacking amongst the respondents. In case of a hazard occurrence, most of the respondents showed that lack of information available to the public was to blame for their lack of knowledge of how to protect themselves. Useful information should comprise specific information about the actual risk, possibilities to personal preventive measures as well guidelines on how to behave in case of an emergency.

Despite the fact that coastal vulnerability is on the increase (Camilleri, 2006), this survey shows that the majority of respondents felt that they were not vulnerable to these hazards. This perception could be caused either by respondents’ lack of information or lack of experience of some of the coastal hazards under study. On a similar note, when asked to evaluate the level of hazard probability occurring along Gozo, the majority of the respondents pointed out that it was quite low. Few respondents stated that the probability was high.

Provision of information to the public is a matter of urgent concern. Regardless of the fact that some respondents pointed out that private agencies did provide information on coastal hazards, the majority argued that information was not available from the competent authorities. Both the local and governmental agencies should take a major role in providing information to the public. Furthermore, it turns out that lack of appropriate mitigation and monitoring schemes and inadequacies in legislations were the most predominant factors identified by respondents as contributing to increased coastal vulnerability. In fact, in Malta (UNEP, MAP, PAP, 2005: 45) there is

“...no specific reference in current legislation to the coastal zone and coastal zone management.”

Most respondents believed that education and awareness schemes appear to be the preferred mechanism to lessen vulnerability. Both the inter-governmental (federal, state and local) and the public can contribute significantly. Schools and public events can in fact be a direct source of information for locals who want to involve themselves in such events whereas the inter-governmental agencies should provide enough opportunities to attract the local’s attention through seminars and other means.
Interest in attending and/or participating in a coastal hazard related event appeared to be high amongst the respondents. Hence, the responsible authorities, private agencies and NGOs should do their best to increase awareness of coastal hazards in seminars, information events and conferences.

A general conclusion that could be drawn from this survey is that coastal risk management is confronted with lack of preparedness, awareness as well as lack of information to the general public about coastal hazards and vulnerability.
Chapter 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CHAPTER OUTLINE

This chapter presents suggestions, proposals and recommendations with respect to the management of coastal hazards on the island of Gozo. The concept of sustainable management underpins the attempt to seek ways of managing and decreasing the risk imposed by the hazards under study.
6.2 KEY FINDINGS

The aim of this research was to evaluate the main areas considered to be at major risk to five different natural coastal hazards; tsunamis, sea level rise, flooding, landslide and storm surge. In the Maltese Islands, research related to this topic is known to be “very limited” (European Commission, 2009: 4), thus this study serves as a fundamental pillar contributing towards a basis for research on coastal hazards and vulnerability in Malta.

A number of key conclusions emerged from the research undertaken and described in previous chapters. Firstly it is evident that risk maps can be compiled effectively using a Geographic Information System, based on the combined results from the application of the vulnerability scoring criteria. Despite Gozo’s small physical size, there is still spatial heterogeneity with respect to vulnerability, with a number of hotspot sites that appear to be at higher risk to coastal hazards than others, especially areas mostly dominated by coastal urbanisation (Figure 5.12). In this regard, coastal populations and settlements, infrastructure, property, local economy and the natural environment could in one way or another be potentially affected by the coastal hazards under study. Table 6.1 summarises the impacts from the occurrence of coastal hazards on Gozo.

<table>
<thead>
<tr>
<th>Table 6.1</th>
<th>Summary of Main Hazard Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hazard</strong></td>
<td><strong>Potential impacts</strong></td>
</tr>
<tr>
<td>Tsunami</td>
<td>Elimination of leisure zones</td>
</tr>
<tr>
<td>Sea level rise</td>
<td>X</td>
</tr>
<tr>
<td>Flooding</td>
<td>X</td>
</tr>
<tr>
<td>Landslide</td>
<td></td>
</tr>
<tr>
<td>Storm surge</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hazards</th>
<th>Elimination of leisure zones</th>
<th>Damage to buildings</th>
<th>Loss of income</th>
<th>Soil and coastal erosion</th>
<th>Damage to agricultural fields</th>
<th>Coastal infrastructure destroyed</th>
<th>Fatalities</th>
<th>Road blockage and inaccessible zones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsunami</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Sea level rise</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Flooding</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Landslide</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Storm surge</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Additionally, due to specific criteria adopted to assess high risk zones, different hazards appear to affect certain coastal areas rather than others. Table 6.2 summarises the main coastal areas at high risk from each of the hazards.

Table 6.2
Summary of Hazard Risk Areas

<table>
<thead>
<tr>
<th>Hazard</th>
<th>High risk areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsunami</td>
<td>Ir-Ramla, San Blas and Mgarr Harbour</td>
</tr>
<tr>
<td>Sea level rise</td>
<td>Marsalforn, Xlendi, Dwejra, ir-Ramla and Mgarr Harbour</td>
</tr>
<tr>
<td>Flooding</td>
<td>Marsalforn, ir-Ramla, Mgarr Harbour and Xlendi</td>
</tr>
<tr>
<td>Landslide</td>
<td>San Blas, Mgarr Harbour, ir-Ramla and to a certain extent Marsalforn</td>
</tr>
<tr>
<td>Storm surge</td>
<td>Marsalforn, Xlendi and Mgarr Harbour</td>
</tr>
</tbody>
</table>

The public survey on coastal hazard preparedness and awareness amongst the local population revealed that the majority of respondents were not prepared for or aware of the potential occurrence of certain coastal hazards along Gozo. Differences in levels of awareness between different age groups also emerged.

Of the various sources of available information, the Internet appeared to be the prevalent source on coastal hazards for the survey respondents. The extent of information provided by competent authorities, on the other hand, appears to be limited with no information service offered. Survey respondents opted for monitoring of the coastal zone as the preferred response to reduce coastal vulnerability.

A sustainable and holistic approach is needed to manage coastal hazards in Gozo. Inadequate preparedness, awareness, and low knowledge distribution amongst the respondents suggests that coastal hazards are not given a priority by the competent authorities. At the same time, there is a need for better scientific understanding of vulnerability to enable appropriate contingency planning.
6.3 THE NEED FOR A SUSTAINABLE APPROACH TO THE MANAGEMENT OF COASTAL HAZARDS

Hazard risk management on the island of Gozo is of crucial importance. It is the process that determines which administrative decisions are taken to implement policies, coping capacities and strategies in order to reduce vulnerability (UNDP, 2002). In Malta, an exercise to formulate a risk management strategy to reduce the risk posed by coastal hazards has so far not been undertaken (European Commission, 2009). Hence, there is a need to strengthen the economic and social resilience and adaptive capacity of vulnerable coastal regions to allow for sustainable development in the littoral zone.

However, during a recent conference in Malta, one week before dissertation submission, the need for a risk reduction strategy was discussed (Times of Malta, 2010b). As highlighted during this conference,

"...it is therefore important that we consider implementing initiatives in Disaster Risk Reduction. Disasters could be mitigated through proper planning and preventive measures. We should work closely together to identify those risks and hazards which can contribute towards catastrophic events. We are aware that the costs involved in the recovery process of a country in the aftermath of a disaster by far surpass those that are needed in implementing prevention measures. Therefore, we believe that more emphasis should be made on this important aspect of Disaster Risk Reduction,"

According to UNDP (2002), three essential elements for risk management need to be taken into account, namely anticipatory, compensatory and reactive risk management.

- Anticipatory risk management refers to the reassurance that future development lessens rather than enhances risk. In fact, raising awareness, emergency responses, improvement in sea defence mechanisms and appropriate land use planning can all reduce hazard probability (and/or the severity of likely impacts) in Gozo. Indeed, this research has been focused primarily on anticipatory risk management.
- Compensatory risk management comprises actions to alleviate the losses linked with the existing risk.
- Reactive risk management signifies the assurance that risk is not re-established after catastrophic events.
Whilst recovery and restoration, and compensation for damages may all be relevant to Gozo in the event of hazard occurrences, there is presently a need to focus on anticipatory measures, i.e. preparedness, to reduce vulnerability and reduce the likelihood of damages.

6.3.1 Policy Recommendations and Proposals for Gozo

The proposals and recommendations listed below primarily aim at improving the current situation with regards to coastal hazards on Gozo.

6.3.1.1 Prevention instead of reaction particularly in high risk areas

Enhancing the resilience of coastal systems is a practical adaptive response to reduce coastal vulnerability (Biljsma et al., 1996). Many negative impacts could be mitigated effectively or simply avoided with practical measures to manage the coast in the light of short, medium and long term resilience. Theoretically, strengthening resilience along the Gozitan littoral zone may be attained by lessening the probability of natural hazard occurrence through:

- Improvements in building construction to resist hazard consequences;
- Promotion of information dissemination on coastal hazard and their potential consequences. Public events are ideal to promote such information to the public. In fact, flyers should be supplied to suit different age groups;
- Improvements of local emergency systems;
- Establishing training programmes;
- Public awareness campaigns to improve understanding of risk;
- Development of early warning systems and contingency plans;
- Training in evacuation drills;
- Zoning of land uses to minimise vulnerability of the most threatened groups.

6.3.1.2 Development of better tools and guidance for decision-making

Geographic Information Systems are an effective mechanism to assist decision makers during contingency planning. For the island of Gozo, GIS can provide considerable support and guidance to coastal managers in accomplishing strategic planning, models
and scenarios especially in high risk coastal zones. In this respect, through the use of buffers and other tools, GIS can aid planners by facilitating the process of:

- Identifying areas at high and low risks from coastal hazards;
- Identifying routes to safer high elevation zones;
- Identifying areas where safety measures could be improved;
- Visually communicating to the general public the various threats along the coastal zone;
- Identifying relative low risk areas where emergency ‘shelter’ to the settlers could be located;
- Identifying areas of highest social, economic and infrastructural vulnerability.

6.3.1.3 Monitoring in high risk zones

Coastal monitoring can be regarded as a very important step in the successful implementation of policies and strategies and in minimising adverse consequences on coastal populations and infrastructure. Unfortunately, only a small number of coastal hazards are being monitored in Malta, which means that there are insufficient data available. Consequently, the current policies cannot cater for all the coastal hazards relevant to this study. To remedy the current deficiencies:

- An immediate evaluation of all the coastal hazards that could occur in Gozo should be accomplished;
- A scientific and technical committee should be appointed to evaluate, monitor and determine the probability of occurrence for coastal hazards;
- Monitoring stations, using gauges and sensors should be installed in low-lying coastal regions especially in areas considered to be at high risk;
- A database should be created to store information while fulfilling monitoring;
- Before coastal policies are implemented, monitoring should be carried out long before to ensure that the best policies are adopted to minimise hazard threats.

6.3.1.4 Public preparedness and awareness

To date, relatively little efforts have been invested in raising public awareness of and preparedness about the consequences of coastal hazards. The outcome of the public survey has confirmed the lack of awareness and preparedness amongst the Gozitan
people. Hence, there is a need for improving general awareness among the public of the potential impacts of coastal hazards and the consequent need to take action. As recently argued; we need to foster education and information sharing to achieve these objectives to minimise catastrophes (Times of Malta, 2010b). Therefore, the following is a list of recommendations to improve the current situation:

- Information offices and free phone lines should be set up to provide the public with the necessary information on coastal hazards;
- Schools should serve as a means to prepare and increase awareness amongst the students;
- Local councils could provide door-to-door consultation, public hearings, community message boards, seminars and educational programmes for different age groups to inform the locals about these natural phenomena;
- Periodic updates, annual reports, websites, and emails by the competent authorities could provide good opportunities for sharing and distributing information to the public on hazard preparedness and awareness;
- Devise evacuation plans as a key mechanism to the public on how to follow certain actions when evacuating coastal zones due to hazard occurrence;
- Posters and signs should be installed in high risk zones for the purpose of informing locals about coastal hazard risks.

6.3.1.5 Coastal defence and risk reduction plans

In the Maltese Islands, only some coastal defence mechanisms and risk reduction plans to protect the coastal zones from the potential impacts of coastal hazards have been undertaken. Planning-related recommendations which are relevant to Gozo are the following:

- Early warning systems should be developed for all coastal zones. These ought to be timely, authoritative and precise to cater for emergency situations with little or no warning;
- Breakwaters, sea walls, sea dykes, rack revetments to existing cliffs, groynes to minimise sediment transport, beach nourishments, and other hard structure techniques can provide a suitable means to enhance and consolidate coastal defence works in the coastal zones. These should be constructed after feasibility studies and EIAs have been conducted;
• Forecasts and hazard prediction systems should be developed to inform authorities, so that appropriate measures can be taken to ensure public safety.

6.3.1.6  **Sustainable coastal planning in high risk areas**

Sustainable coastal planning is of high importance especially where high risk regions are located. As further argued in the Times of Malta (2010b)

...research, land use planning and legislation on safety standards are also required to complement this process.

In this respect, integrated coastal zone management should be an on-going process in the coastal zone to strike a balance between different sectors especially in the planning phase. Furthermore, vulnerability assessments could be a useful tool when planning for new developments. In Gozo, the main areas known to be at major risk are densely urbanised especially within the limits of Xlendi, Marsalforn and Mgarr Harbour. Hence, to prevent unintended consequences from occurring, development should be limited in areas of high risk and relocated to areas of lower risk – even if such a measure would present many challenges. Moreover, integrating risk management with coastal planning should also be taken into consideration. This could be achieved by promoting coastal zones that are less vulnerable to coastal hazards.
6.4 CONCLUDING REMARKS

On the island of Gozo there are several coastal regions considered to be at risk from multiple natural hazards. Indeed, such events could generate several adverse consequences, and negative impacts on coastal populations, societies, infrastructure, belongings and the local economy. Thus, a better coastal management approach can contribute to a decrease in such hazards. Section 6.3 provides several recommendations and proposals that should feature in a management framework prepared by the local authorities.

Hazard preparedness and awareness ought to be given top priority and importance by the competent authorities to inform the general public about the existence of several coastal hazards to the island of Gozo. In this regard, given an unexpected hazard occurrence, the general public would know how to react to such a scenario.

All relevant stakeholders (including politicians, Local Councils, MEPA, Non-Governmental Organisations and the general public) should contribute to decrease coastal vulnerability to the different hazards on the island of Gozo through appropriate means compatible with sustainable management.
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APPENDIX 1

GOZO AND COMINO MAP
APPENDIX 2

QUESTIONNAIRES
Assessing Vulnerability to Coastal Hazards

Case Study: Gozo

The main aim of this questionnaire is to investigate the level of awareness and preparedness that Gozitan people have, with regard to coastal hazards. A coastal hazard is a natural phenomenon, with the ability to cause potential damage to humans, assets, natural ecosystems and infrastructures. This survey addresses five potential coastal hazards: (i) tsunami, (ii) storm surge, (iii) sea level rise, (iv) flooding and (v) landslide.

a. Gender:
   Male
   Female

b. Age:
   15-30
   30-45
   45-60
   60+

Questionnaire Part I – Risk Perception

1. Which of the following coastal hazard terms are you familiar with? (Tick any or all that apply)
   - Tsunami
   - Sea level rise
   - Storm surge
   - Landslide
   - Flooding
2. Referring to question 1, from where have you learnt about coastal hazards? (tick any or all that apply)

<table>
<thead>
<tr>
<th></th>
<th>Tsunami</th>
<th>Sea level rise</th>
<th>Storm surge</th>
<th>Landslide</th>
<th>Flooding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local authorities</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Neighbours/ friends</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Internet or other media</td>
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<td></td>
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</tr>
<tr>
<td>Civil protection</td>
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</tr>
<tr>
<td>School/Educational facilities</td>
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</tr>
</tbody>
</table>

3. Do you consider yourself vulnerable to any of the five coastal hazards? (tick for all five hazards)

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>Unsure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsunami</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sea level rise</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storm surge</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Landslide</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flooding</td>
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</tbody>
</table>

4. In your opinion, what is the level of knowledge regarding any of the five coastal hazards?
   - Well informed
   - Moderately informed
   - Not informed at all

5. In your opinion, what is the probability of any of these five coastal hazards occurring along the Gozitan coastline? (tick for all five hazards)

<table>
<thead>
<tr>
<th></th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsunami</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sea level rise</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Storm surge</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Landslide</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flooding</td>
<td></td>
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</tbody>
</table>
6. In case of the occurrence of a coastal hazard, do you know how to protect yourself?
   - Yes
   - No
   - Unsure

7. Referring to question 6, how have you learnt about personal protection in the event of a hazard?
   - Local authorities
   - Government services
   - Private agencies and NGOs
   - No information offered

8. How would you rate the provision of information about coastal hazards by the responsible authorities?
   - Very helpful
   - Satisfactory
   - Poor service
   - No service offered

9. What do you think is contributing to an increase in coastal vulnerability along this littoral zone? (Tick any or all that apply)
   - Lack of appropriate mitigation and monitoring schemes
   - Inadequacies in legislations
   - Poor communication systems
   - Incomplete availability of coastal data
   - Insufficient planning and awareness techniques
   - Lack of coordination between stakeholders
10. In your opinion, are there sufficient protective mechanisms to protect the coast of Gozo in the event of coastal hazards?
   - Yes [ ]
   - No [ ]
   - Unsure [ ]

11. What do you suggest to be done to lessen coastal vulnerability?
   - Already enough methods of protection [ ]
   - Monitoring the area [ ]
   - Introduce new techniques and types of construction [ ]
   - Increase in early warning systems [ ]
   - Increase in education and awareness schemes [ ]
   - Other [ ]

Questionnaire Part II – Participation

12. Have you ever taken part in a public event concerning coastal hazard preparedness/awareness and/or coastal protection?
   - Yes [ ]
   - No [ ]

13. Referring to question 11, what type of event was it?
   - Workshops [ ]
   - Information event [ ]
   - Conference [ ]
   - Never encountered any public event about this topic [ ]
   - Other [ ]
14. Would you be interested in participating in future events concerning coastal hazards?

- Yes
- No

Thank you for all your help

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