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Investigating the compatibility between Natura 2000 site protection and geomorphological landscapes

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INVESTIGATING THE COMPATIBILITY BETWEEN
NATURA 2000 SITE PROTECTION AND
GEOMORPHOLOGICAL LANDSCAPES

Faye Zammit

M.Sc. in Sustainable Environmental Resource Management
& Integrated Science and Technology

October 2012

INVESTIGATING THE COMPATIBILITY BETWEEN
NATURA 2000 SITE PROTECTION AND
GEOMORPHOLOGICAL LANDSCAPES

FAYE ZAMMIT

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

October 2012

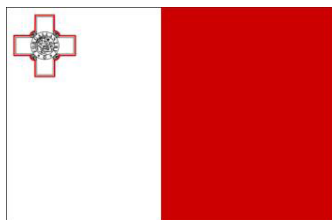
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ABSTRACT

Natura 2000 was established under the 1992 Habitats Directive as a EU wide network of nature protection areas by ensuring long-term survival of Europe's most valuable and threatened species and habitats. Under the Natura 2000 scheme, there are a total of 32 protection areas in both Malta and Gozo.

The different structural properties of the various rock layers results in various characteristic formations which are of ecological importance providing important refuge for many Maltese flora and fauna.

In Malta, the different geomorphologic features are mainly a result of tectonic movement in which some are still dynamic and over the years will change. As this change occurs, habitats will change and the biota within will be forced to adapt to this change in the abiotic environment. This may result in a change in distribution patterns of species, as competition for niche space may lead to further changes in the overall make-up of the floral assemblage, which will in-turn have an impact on the fauna that depend on the habitat in question. Such modifications within the terrain, may threaten the status of certain species depending on their adaptation and vulnerability to change. The threats on geomorphology are the key factors in compatibility with ecology protection.

The examination of the Natura 2000 sites along with the mapping of the geomorphological features shaping these habitats has shown a link between the two. Through this a series of conclusions and a number of recommendations have been drawn out based on these findings.

STATEMENT OF AUTHENTICITY

I, the undersigned, declare that the work being presented is authentic and has been carried out under the supervision of Dr.Louis F. Cassar and Ms.Elisabeth Conrad.

Faye Zammit

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Chapter 1

Introduction

Chapter 1

Introduction

1.0. Conceptual Framework

Natura 2000 is a network of nature protection areas under the 1992 Habitats Directive. These protected areas consist of Special Areas of Conservation (SAC) and Special Protected Areas (SPA). The main feature of this policy is to encourage and maintain positive human activities in these reserves to ensure present and future management is sustainable, both ecologically and economically. Malta has designated a total of 34 terrestrial Natura 2000 sites: 27 terrestrial SACs and 13 SPAs (6 sites are protected under both designations), covering almost 20% of the land area of the Maltese archipelago (MEPA, 2012).

22 of the above mentioned sites are largely located on the southern coast of Malta. Most of the 190km coastline is composed of a block of Oligo-Miocene limestones (Oil Exploration Division, 1993, Magri, 2006). Geologically, one observes a simple layer arrangement of Lower and Upper Coralline Limestones with intervening layers of soft Globigerina Limestone, Greensand and Blue Clay. This tertiary sequence of successive sediments of rock, were deposited in a variety of shallow water marine environments. The 190km coastline of the islands is almost entirely made up of sedimentary rock deposited in a marine environment during the Oligo-Miocene period forming many geomorphological features (Azzopardi, 2002).

This combined influence of climate and geo-tectonics has brought about the formation of characteristic geomorphological features. These include hillsides overlain with clay taluses, karstic limestone plateaux and gently rolling limestone plains (Magri, 2006). As tectonic activity has been the predominant factor to the formation of the typical local landscape, one predominantly comes across faulting, up arching and subsidence. The following geographical features are seen:

- a) Highest areas- coralline limestone plateaux
- b) Coastal areas and valleys- Blue Clay slopes
- c) Undercliff areas (rdum) are to be found where Blue Clay slopes descend steeply to the sea

- d) Flat floored basins (e.g. Pwales Valley)
- e) Globigerina Limestone hills and plains including large areas of gently sloping land (Magri, 2006).

Dingli Cliffs in Malta and id-Dbiegi in Gozo are the relative highest sites, above mean sea level, in the respective Islands. Both islands are tilted seawards to the NE.

Two major faults running across Malta influence its topography. This geological formation has predisposed human activities to be more dominant, varied and tourist related in the low-lying, N.E. side of the coast. On the other hand, the southern cliff areas are dominated by agriculture. Various rock layers have been affected structurally by bilateral wind and wave erosion resulting in various formations: karstland, bays, boulder screes, wave cut notches and shore platforms (Azzopardi, 2002). These features are of ecological importance providing important refuge for many Maltese flora and fauna. Considering the island's small land area, limited number of habitat types and intense human pressure there is impoverished flora and fauna. Each geomorphological feature often provides habitat to a variety of ecological communities; woodland, maquis, garrigue, steppic grasslands, communities of disturbed ground, coastal communities, rupestral communities, freshwater communities and caves (Lanfranco, 1986). The various geomorphological factors have influenced the development of an extensive variety of ecosystems.

On the negative side, human impact has escalated since early humans settled on the islands, way back at 7000BP (Haslam, 1989). During the early days of colonization, the main human activity was (and still is partially) agriculture. The eventual introduction of sheep and goats prevented the regeneration of tree. Modern human activity with urban development intensified the deforestation process. As man has proved to be the main destructive factor to the loss of habitats and eventual extinction of indigenous species and vast tracks of woodland, the Natura 2000 scheme will help in no small measure to sustain our local environment as a whole. This will sustain the geomorphology of our islands, whereby man and nature will interact positively. Such an approach will help a conservation status for all species (including humans) and habitats, thus sustaining their well-being on a long term basis. It ought to be remembered that it's the environment in which species thrive that need to be protected in order to afford adequate space for species-species and

species-habitat interactions and to ensure a favourable conservation status of both species and habitats in the long term.

1.1 Justification

What has mainly shaped the geomorphology of the Maltese archipelago is due to continual tectonic movement. As this has not ended, the habitats in the Natura 2000 sites will have to continually adapt and evolve to the never-ending changes to enable to survive. Flora and fauna in all related ecosystems will be competing with each other. As this change occurs, habitats will change and the biota within will be forced to adapt to this change in the abiotic environment; this may result in a change in distribution patterns of species, as competition for niche space may lead to further changes in the overall make-up of the floral assemblage, which will in-turn have an impact on the fauna that depend on the habitat in question. Such modifications within the terrain, may threaten the status of certain species depending on their adaptation and vulnerability to change. Unless their adaptation is sufficient, extinction of various species may occur. The threats on geomorphology are the key factors in compatibility with ecology protection. Such an example is a valley, being a dynamic feature (from the geomorphological, hydrological, ecological and anthropic points of view); those species present in this environment will suffer unless holistic protection is afforded, and this largely includes the geomorphological element. Malta, having such a restricted land area; an island state, needs to integrate conservation, thus not only taking ecology into consideration but also the associated geomorphology.

All this justifies ecology protection by providing adequate frameworks to evolve the sustainability of the protected sites. Holistic protection would have to be organised and maintained to ward off all natural and human threats to the geomorphology of all ecosites.

1.2 Aims and Objectives

The main aim is to thoroughly examine 2000 sites in Malta focusing on the interactive link between these habitats and their particular, associated geomorphology. Objectively, this investigation may enable local authorities to

upgrade their policies of protection to the sites in question. Better guidelines are needed as the present ones only protect directly the species living in these ecosystems, without considering the paramount fact that all flora and fauna depend on specific habitat requirements, the landform of which is made up by the geomorphological processes that operate within the site per se. Hence, all factors bringing about drastic and negative effects to the geomorphology would have to be appraised and subsequently controlled. The present study intends to highlight this importance of geomorphology within the N2K sites by linking the importance of existing species with:

- i. Their respective habitat
- ii. The landform (geomorphology) per se.

The present boundaries of each Natura 2000 site will be examined as they currently stand, i.e., as per scheduling criteria and the reason for which these sites are protected (hence, species-based) and from the point of view of geomorphology. The ‘watershed divide’ approach will be implemented. Due to time constraints only the Natura 2000 sites in the main island of Malta will be investigated. The study will concentrate on Wied Babu, heading up north to Qassisu (Cirkewwa) to Tal-Mignuna. By mapping important features and explaining the relationships between forms, materials, processes and landform development the field inspection will be complemented with image interpretation to enable full visualization of the inspected sites.

1.3 Dissertation Outline

Chapter 1: Introduction. This chapter seeks to introduce the topic of the study. It provides a brief overview of the landscape, geomorphology and ecological communities of the Maltese Islands, briefly outlining the link between biodiversity and geomorphology. It presents a general description of the area under study and lists the main aim and objectives of this study.

Chapter 2: Literature Review. This chapter reviews literature on the idea of bio-conservation and geo-conservation with emphasis on the importance of the latter linked with the former. A number of European and local policies on biodiversity are reviewed emphasising the lack of importance on geo-conservation.

Chapter 3: Site/s Description. This chapter provides a detailed overview of the main geographical characteristics, physical components and biodiversity in each site of study.

Chapter 4: Methodology. This chapter details the methodological approach for each distinct stage of this study: i) a desk study, ii) ground-truthing, iii) Digitizing, iv) an analysis of the link between the habitats and geomorphology of the studied sites. It highlights the main analytical techniques and refers to the main limitations of this study.

Chapter 5: Results and Analysis. The main outcomes from all the ground-truthing and desk-study of the Natura 2000 sites are presented and analyzed with the aid of maps and GIS.

Chapter 6: Conclusions and Recommendations. This chapter provides a summary of the key findings of this study and draws out a series of conclusions based on these findings. A number of recommendations are also presented.

Chapter 2

Literature

Review

Chapter 2

Literature Review

2.0 Conservation

The importance of conservation has increased through the growing interest in the biology and ecology of the natural environment with the introduction of many more sites of high scientific value (Ratcliffe, 2011). A large number of key areas are taken into consideration in terms of conservation representing all major types of natural and semi-natural vegetation as well as their characteristic assemblages of those habitat conditions of plants and animals, topography, rocks and soils, biotic influence and climate. A vital part of conservation is to make biodiversity robust to environmental change thus conserving and restoring habitats at a landscape scale is of significant importance (RSPB, 2005). The IUCN defines a protected area as

“an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means” (IUCN, 2000).

2.0.1 Biodiversity

Out of the several million diverse species the planet inhabits, 1.8 million have been identified by scientists (Kearns, 2010). These species range from giant organisms like blue whales and Pando which is a clonal stand of aspen trees covering 106 acres weighing 13million pounds, to tiny single-celled microbes with a 400nm diameter (*Ibid*). The most familiar multi-cellular organisms such as plants and animals only form small branches of the tree of life (*Ibid*). Species have their own ecological requirements each with a specific niche setting them apart and making them unique (RSPB, 2005). Estimates suggest that there 5-15 million species on this planet and over 15,000 are described each year (Kearns, 2010). Species can be used as an indicator towards the health of the environment (RSPB, 2005).

2.0.2. Threatened Species

Available conservation resources are far outstripped by the number of species threatened with extinction (Myers Norman, 2000). Present-day extinction rates are 1000 to 10000 times greater to the natural background extinction rate (European

Comission, 2012). The International Union for Conservation of Nature (IUCN) estimates that 14% of birds, 22% of mammals and 32% of amphibians are threatened with extinction globally (*Ibid*). In Europe some 45% of butterflies and reptiles, 42% of European mammals, together with 15% of birds are endangered (European Comission, 2012). 131,399 (43.8%) of all species of vascular plants and 9681 (35.5%) of endemic non-fish vertebrates form part of the world's hotspots (Myers Norman, 2000). These comprise only 11.8% of the land surface of the Earth confined to 25 hotspots within terrestrial eco-regions, mainly tropical and Mediterranean (*Ibid*) (refer to figure 2.1). Hotspots are those areas experiencing exceptional loss of habitats which feature abundant concentrations of endemic species (*Ibid*). Biodiversity is declining and ecosystems are continuously being degraded as a result of a variety of pressures such as population growth, urbanisation, climate change, changing diets and many other factors (European Comission, 2012). Both on a local and national scale, a number of wild species have become threatened or extinct in the Maltese Islands either due to the geographical isolation and small size or by drivers of biodiversity change (MEPA, 2012). The Millennium Ecosystem Assessment is a compilation of reports on the dependency of humans on biodiversity and the issue of drivers of biodiversity change (*ibid*). Its main objective is to:

“Assess the consequences of ecosystem change for human well-being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being” (MEPA, 2012).

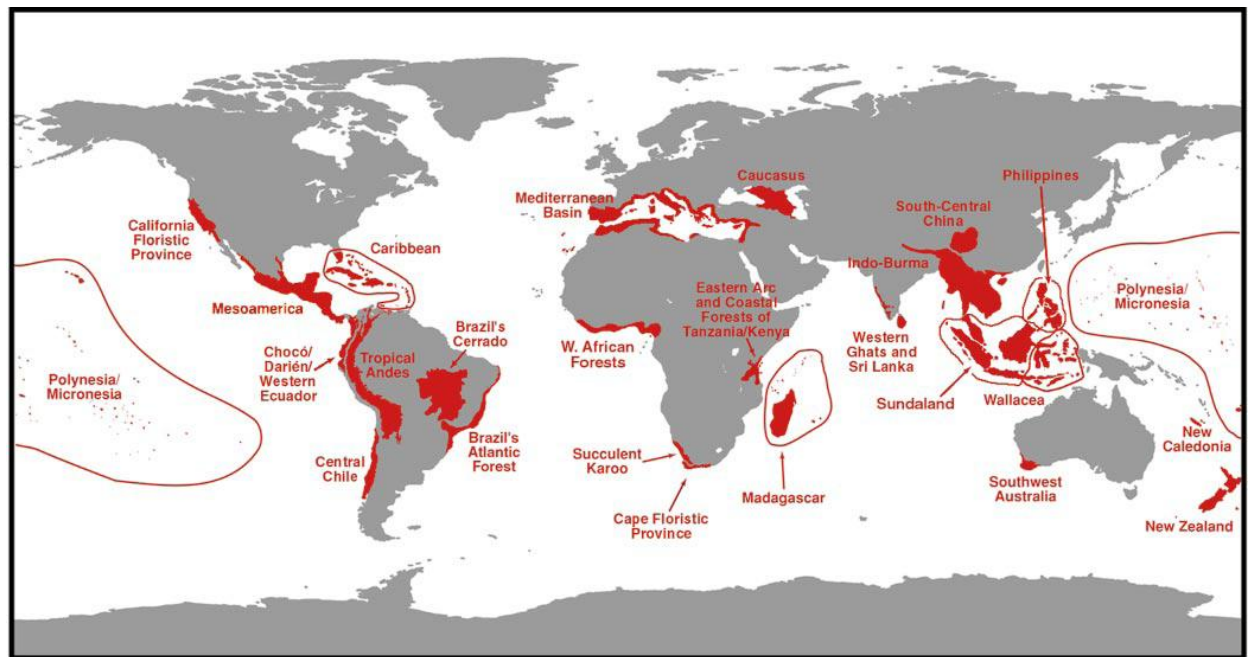


Figure 2.1: Showing the 25 hotspots in the world. Source: (Myers Norman, 2000).

2.0.3 Why should biodiversity conservation be a priority?

With over 7,000 species of plants needed for food and the dependency on plants for medicines, should concern humans becoming more aware about saving biodiversity due to its ecosystem services and biological resources (Kearns, 2010). Water and air purification, timber, fisheries and nutrient cycle provide ecosystem services which human well-being depends on (European Commission, 2012). Leopold amongst other nature writers emphasize on the intrinsic values of biodiversity rather than modern arguments focusing on the anthropocentric value of biodiversity. The Earth's species offer benefits to provide new solutions to existing problems thus conserving nature helps us solve problems yet to be discovered. The Amazon wilderness stores the largest flows of fresh water all over the world. By securing the ecosystem and retaining the availability of fresh water for future generations, the value of such areas will grow. As well as the pharmaceutical industry, other research and developing sectors have begun to revitalise bio prospecting in fields such as bio fuels, biotechnology etc (Conservation International, 2012). Conservation International together with governments on a local, regional and national level all around the world deal with areas of concern which have high priority.

Conserving biodiversity is about species, genetic diversity, habitats and ecosystems. Biodiversity conservation provides substantial benefits such as clean, consistent water flows, protection from floods and storms as well as a stable climate, to meet immediate human needs' i.e. ecosystem services (Conservation International, 2012). Nature should be maintained not only for own needs but for the benefit of our descendants. Humans should be concerned about conserving biodiversity because of the benefits it provides such as biological resources and ecosystem services (Kearns, 2010). To ensure species' perpetuity it is of importance to know which species are present within specific areas by applying conservation measures and adopting sustainable practices (MEPA, 2012). Conservation International strives to ensure that human societies value the services nature provides.

“Conservation is not just about avoiding extinctions but about restoring or recovering species populations to secure levels, and preventing other species from reaching such a perilous situation in the first place” (RSPB, 2005).

2.0.4. European Union Biodiversity Policies

As a result of the growth of conservation, many nature reserves have been set up worldwide. At the meeting of the ministers of environment in March 2007 the study on 'The economic significance of the global loss of biological diversity' was proposed by the German government and was then endorsed at the Heiligendamm Summit on 6-8 June 2007 (European Commission, 2012). This was then turned into a global study named "The Economics of Ecosystems & Biodiversity (TEEB) by the German Federal Ministry for the Environment and the European Commission, with the support of several other partners. By evaluating the costs of the loss of biodiversity and the associated decline in ecosystems serviced worldwide, this study will sharpen the awareness of the value of ecosystem services biodiversity (*ibid*). In 1992 the Habitats Directive which complements the Birds Directive adopted in 1979 was designed by the European Governments. This was designed to protect the most seriously threatened species and habitats across Europe. Natura 2000 was established as a network of sites at the heart of both the Habitats Directive and Birds' Directive (Natura 2000, 2007). Under this network, the most valuable and threatened species and habitats of EU countries are assured a long-term survival. The countries involved and the percentage of territory is shown in table 2.1. The network incorporates Special Protection Areas (SPAs) which they designate under the 1979

Birds Directive and is comprised of Special Areas of Conservation (SAC) designated by Member States under the Habitats Directive (European Commission, 2012). The SPAs help to protect and manage areas of importance used for breeding, feeding, and migration or wintering by rare and vulnerable birds (Natura 2000, 2007). On the other hand the SACs provide increased protection and management to rare and vulnerable plants, animals and habitats (*ibid*). Similarly, The IUCN is a global environmental organization founded in 1948 consisting of more than 1,200 member organizations. The IUCN conserves biodiversity through tackling climate change, achieving sustainable energy, improving human well being and building a green economy. The IUCN's Programme is discussed and approved by Member organizations every four years at IUCN's World Conservation Congress. In the programme, the framework for planning, implementing, monitoring and evaluating the conservation work are provided (International Union for Conservation of Nature (IUCN), 2000). On a local level, Nature Trust Malta is a non-profit non-governmental environmental organization that deals with the natural environment of the Maltese Islands. It helps protect endemic plants and animals from extinction as well as projects such as afforestation, habitat conservation and the creation of marine protected areas (Nature Trust Malta, 2012).

Region	Countries involved	% of EU territory
Atlantic	Belgium, Germany, Denmark, Spain, France, Ireland, Portugal, Netherlands, United Kingdom	18.4
Boreal	Estonia, Finland, Latvia, Lithuania, Sweden	18.8
Continental	Austria, Belgium, Bulgaria, Czech Republic, Germany, Denmark, France, Italy, Luxembourg, Poland, Romania, Sweden, Slovenia	29.3
Alpine	Austria, Bulgaria, Germany, Spain, Finland, France, Italy, Poland, Romania, Sweden, Slovenia, Slovakia	8.6
Pannonian	Czech Republic, Hungary, Romania, Slovakia	3.0
Steppic	Romania	0.9
Black Sea	Bulgaria, Romania	0.3
Mediterranean	Cyprus, Spain, France, Greece, Italy, Malta, Portugal	20.6
Macaronesian	Spain, Portugal	0.2

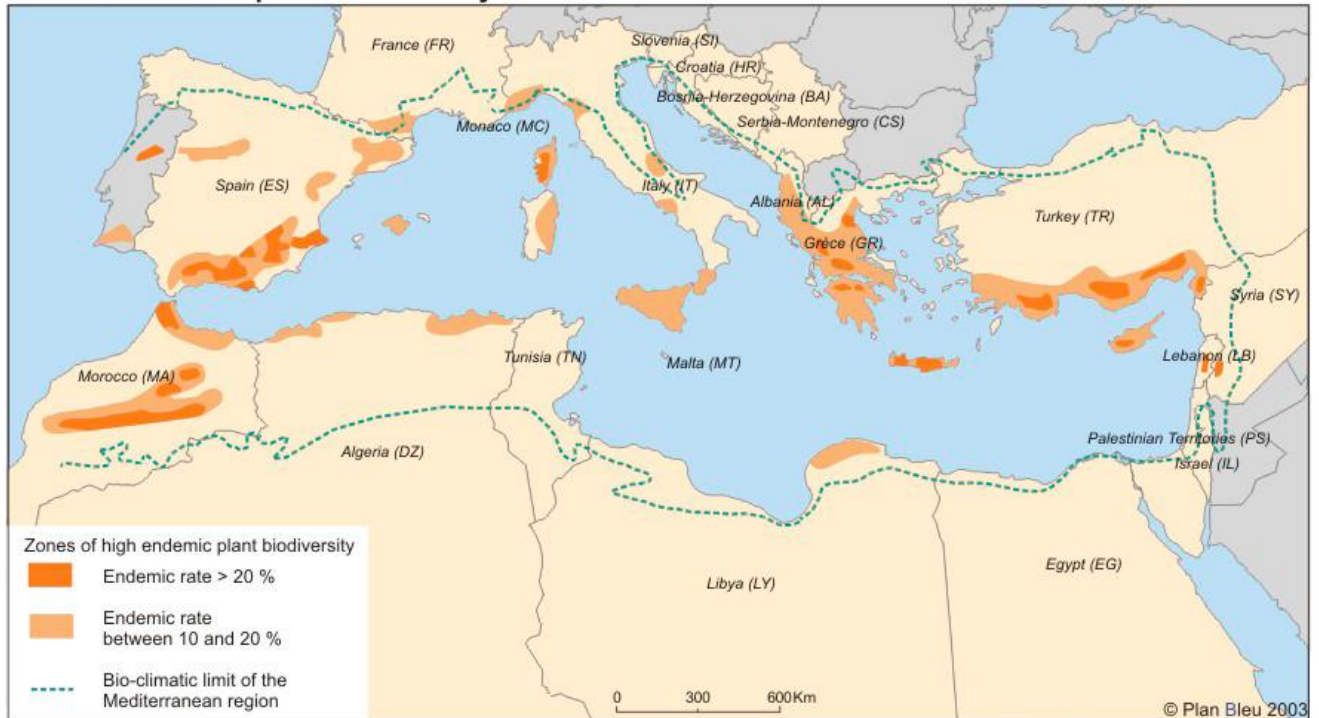
Table 2.1: Showing the different countries involved in Natura 2000 (Source: European Topic Centre on Biological Diversity (European Environment Agency) <http://biodiversity.eionet.europa.eu> October 2008.

2.1. Natura 2000

2.1.1. The Mediterranean Region

The Mediterranean basin stretches at a distance of 3,800km east to west from the tip of Portugal to the shores of Lebanon and 1,000km north to south from Italy to Morocco and Libya. A series of geo-tectonic and geographical events which occurred over a wide range of spatial and temporal scales characterized the formation of the Mediterranean (Cassar, 2010). The varied and contrasting topography of the Mediterranean Region provides harbour for its own special kind of wildlife and habitats with a large number of endemic species (Sundseth, 2009). The Mediterranean supports 25,000 flowering plants which represent 10% of all plants identified on earth with more than half endemic to the region (*ibid*) (refer to figure 2.2). The Mediterranean scrub has developed into a complex patchwork of habitats. The Mediterranean forests harbour up to 100 different tree species making them the most diverse environments in central and northern Europe. Other parts of Europe are far too arid to support a dense vegetation cover. However, these areas may be deceiving as they reveal an equally rich wildlife. Based on scientific criteria, wetlands have been identified as SPAs due to their international importance for migratory waterfowl (European Commission, 2012). These wetlands, ranging from large deltas across the coastline to tiny lagoons act as stepping stones to two billion, yearly migrating birds in the Mediterranean Region. Some birds come down to enjoy the warmer winter climate escaping from the cold, further north whereas others stop for a few days or weeks to refuel before travelling across the Sahara (Sundseth, 2009). The cliffs bordering the western side of the Maltese islands harbour a variety of endemic species and serve as a shelter for a number of breeding birds (MEPA, 2012). The Mediterranean Sea harbours a tremendous diversity of marine organisms (8-9% of the entire world's marine species) most of which are endemic to the region.

Endemic nature of plant bio-diversity



Source : d'après Quézel (1995)

Figure 2.2: Riparian countries and zones with high level of endemic plant biodiversity in the Mediterranean bio-climate area. Source: A sustainable future for the Mediterranean, the Blue Plan's Environment and Development Outlook, 2006.

Through centuries of human induced activities such as forest fires and livestock grazing and cultivation, humankind has left its mark on much of the Mediterranean landscape. The poor Mediterranean has resulted from several factors such as growing vulnerability to natural hazards, ageing populations, unemployment and poor economic performance and environmental crisis (Comeau, 2006). Another factor is the environmental policies remaining top-down and has not been allocated the appropriate resources or inter-ministerial support. Water resources are limited and unequally shared in time and space with just the southern countries only having 13% of the total resources (Comeau, 2006). During the second half of the twentieth century water demands doubled and by 2025 studies show that it could further increase by 25% in the South and East (*ibid*). This growing pressure has resulted in a change in the water regimes, receding deltas, excessive drop in the underground water table levels, water quality degradation, increasing costs and conflicts, shrinking of wetlands and irreversible losses (*inbid*). This obliged the EU to

introduce the EU Water Framework Directive in 2000. This Policy has helped to get waters clean again ensuring that they are kept clean (European Commission).

2.1.2. Natura 2000 Species in the Mediterranean and Maltese Islands

The Mediterranean Region harbours more plant species than all the other European biogeographical regions combined. However the Mediterranean region is a global biodiversity hotspot (IUCN, 2012). Almost half the plants and animals listed in the Habitats Directive are found in the Mediterranean region. Malta submitted a number of sites to the EC Habitats Directive in 2004 to form part of this important network (MEPA, 2008). There are a total of 2,000 species of plants and over 3000 species of animals with the foundation vegetation types being maquis or mattoral and garrigue in the Maltese Islands (Cassar, 2010). The Maltese Rock Centaury *Cheirolophus crassifolius* which only occurs on the blustery cliffs of Malta is an example of one the high number of palaeoendemics which are a result of the varied landscape and restriction to just a few localities. Plants have developed xerophytic adaptations in such ways such as leathery and/or hairy leaves hairy leaves to reduce water loss. The Mediterranean Region is also home to the majority of reptiles found in Europe such as the leopard snake and Iberian rock lizard (Sundseth, 2009). The Mediterranean provides an ideal refuge for migrating birds through the availability of tranquil wetlands and other habitats (European Commission, 2012).

2.1.3. Natura 2000 sites and habitats in the Mediterranean Region and Maltese Islands

In the Mediterranean Region there are a total of 2,928 Sites of Community Importance (SCIs) under the Habitats Directive. Further 999 Special Protection Areas (SPAs) are covered by the Birds Directive. Together these cover around 20% of the total land area in the region (Refer to table 2.2). However, in Malta there are a total of 28 Sites of Community Importance which eventually became Special Areas of Conservation under the EC Habitats Directive and 13 Special Protection Areas under the EC Birds Directive (MEPA, 2008). The list of these Natura 2000 sites was first adopted in July 2006 and further updated in March and December 2008 (Sundseth, 2009).

Forests and scrub cover over half of the Mediterranean Region in which the forests tend to be more open due to hot conditions (Mazzoleni & Di Pasquale, 2004). This allows the growth of a rich understory of shrubs and bushes with much more species diversity than northern forests. The Mediterranean scrub, depending on its location, soil, degree of degradation, human usage and species competition, is also known as, matorral, maquis, garrigue and phrygana, varying in shape and size (Pinborg, 2004). However, although classified differently, these habitats form a mobile mosaic pattern across the landscape as they merge into one another. The maquis is dominated by small trees such as the strawberry tree *Arbutus unedo*, the lentiske *Pistacia lentiscus*, the wild olive *Olea europaea* or the myrtle *Myrtus communis*, or less frequently, the juniper and laurel which form dense impenetrable thickets 1–4 metres high (Sundseth, 2009). On the other hand, garrigue vegetation barely reaches knee height and is far more open (Mazzoleni & Di Pasquale, 2004). Also evident are the leathery leaved plants like rock-roses. Along the coast one might find phrygana composed of spiny cushion forming bushes and ground-hugging shrubs which are all the lowest form of scrub (*ibid*).

40% of the Mediterranean region is occupied by agricultural land and grasslands varying between low key mixed farming systems to large intensively used areas of crops and olive or citrus groves (Pinborg, 2004).

A number of different micro-habitats that are a haven for steppic birds have been created in the dry grasslands which are now being used by farmers to grow oats, barley and chickpeas on the poor soil through crop rotation allowing the soil to recover (Sundseth, 2009).

On the other hand, the Mediterranean pine forests, often dominated by the Black Pine *Pinus nigra*, develop into a closed canopy reaching over 30 metres in height. Mature black pines provide an ideal nesting site for European raptors like the Cinerous vulture *Aegypius monachus* (Pinborg, 2004).

Most wetlands, besides a few major rivers, are found along the coast usually near various deltas and lagoons such as the Ebro delta in Spain. These support an adequate number of birds, rare endemic fish, amphibians and insects (Mazzoleni &

Di Pasquale, 2004). The Mediterranean coastline can “alter from rocky coasts to a white sandy beach backed by extensive dunes to a high cliff face or a vast subterranean sea cave” (Sundseth, 2009). Thus, it is extremely complex and varied supporting many of Europe’s breeding sea birds such as the Eleonora’s falcon *Falco eleonora*. The Mediterranean Sea is very rich in biodiversity with a total of 10,000 to 12,000 recorded marine species (Divesitedirectory, 2008) and 20% of all marine species can only be found in this basin (WWF, 2011). The marine plant *Posidonia oceanica* forms dense underwater meadows along the seafloor reaching a depth of 40metres and is endemic to the Mediterranean Sea. They are exceptionally rich in wildlife providing a safe habitat for millions of tiny marine organisms acting as a nursery ground for commercially valuable fish. Posidonia is also important as it traps sediment, oxygenates the water and prevents erosion which helps to protect the coastline. It also acts as an indicator of water quality as it can only grow in clean nutrient-poor waters. Seagrass act as a “carbon sink” by protecting the planet from the increasing amount of carbon dioxide therefore helping to slow down the effects of global warming (Divesitedirectory, 2008). Unfortunately, due to fishing activities, recreational boating, dredging, pollution and sand abstraction amongst others, almost half of the Posidonia in the Mediterranean has disappeared (*ibid*).

Ecosystems undergo ecological succession and the habitats in the Maltese Islands appear at different stages. The habitats occur as a mosaic of a total of four different stages of ecological succession those being steppe the first stage, maquis the second stage followed by garrigue and woodland (MEPA , 2012). Habitats are divided into terrestrial and marine each with their own types and zones (refer to table 2.3). As a result of the high human population, communities of disturbed ground is present also have a large coverage dominated by a variety of plant species (Schembri, 1993).

Region	Habitat types	Animals	Plants
Atlantic	117	80	52
Boreal	88	70	61
Continental	159	184	102
Alpine	119	161	107
Pannonian	56	118	46
Steppic	25	25	14
Black Sea	58	79	6
Mediterranean	146	158	270
Macaronesian	38	22	159

Table 2.2: Showing the number of habitat types in Annex I and species or sub-species in Annex II of the Habitats Directive (Source: European Topic Centre on Biological Diversity (European Environment Agency) <http://biodiversity.eionet.europa.eu>).

Terrestrial Habitats		Marine Habitats	
Coastal	Saline Marshlands	Supralittoral	Rocky Shore
	Rainwater Rockpools		Sandy Shore
	Sand dunes		Posidonia banquettes
Freshwater	Valley Watercourses	Mediolittoral	Upper
			Middle and Lower
			Soft substratum shores
Rupestral	Caves	Infralittoral	Hard bottom assemblages
	Cliffs		Soft bottom assemblages
		Cirralittoral	Coralline Communities
			Maerl Communities

Table 2.3: Showing the terrestrial and marine habitats divided in their own types and zones. Source: Compiled by author, data from MEPA, 2012.

2.2. Management issues in the Mediterranean

The Mediterranean Region is the main supplier for agricultural products around the world. The wild plants found in this region produce olives, barley, wheat, oat grapes, figs, peas, almonds, vegetables, fruit and medicinal or aromatic herbs. The Mediterranean is one of the most important centres worldwide for crop plants according to the FAO (Sundseth, 2009). Subsidence style farming activities has changed the composite of several habitats. Cultivated terraces, constructed as a result of the hilliness of the landscape, prevent erosion and retain water being an ideal environment for the growth of fruit and vegetables. Maltese terraced landscape are quite distinct as these are the products of several centuries of dedicated soil

conservation practise in which some sort of arable cultivation was permitted despite the inhospitable topographic and climatic environment (Role, Experiences in Malta on the Management of Terraced). Retaining water is vital as in the hot, dry Mediterranean climate; soil and water are precious resources. However, terraced fields are now threatened by successive waves of intensive urbanisation pressures (*ibid*). Both the vine and the olive tree can adapt well to harsh conditions with poor soil conditions and limited water supply- thus these are still a characteristic in the Mediterranean (Mazzoleni & Di Pasquale, 2004). However, natural resources are used in the best of ways through sustainable farming systems practised on flatter land and in the plains. Over the last 50 years, agricultural practises have changed with industrial scale fruit or olive plantations replacing ancient vineyards, orchards and olive groves and intensive monocultures replacing mixed rotational farming (Sundseth, 2009). Due to this revolution, there has not only been a loss of wildlife habitats but a major social economic impact forcing farmers to abandon their land and look for jobs elsewhere.

Wild fires have become more regular damaging property and wildlife as they sweep across the region in late summer with an average of 50,000 fires 600,000ha burnt in the Mediterranean per year (Alexandrian, Esnault, & Calabri). Only 1% to 5% out of the total forest fires in the Mediterranean are from natural origin, whereas human-induced fires represent more than 95% (WWF). These are the most important natural threat to forests and wooded areas in the Mediterranean basin (Alexandrian, Esnault, & Calabri). Wildfires destroy many more trees than all other natural calamities: parasite attacks, insects, tornadoes, frost, etc (*ibid*). With a high demand of water irrigation, pesticides and fertilisers in modern farming practises, high pressure is being put on the surrounding environment. Chronic water shortages are a contributing factor through the increasing tourism development and urbanisation.

According to the UNEP, the number of tourists visiting the Mediterranean has risen from 58million in 1970 to 228 millions in 2002. The Mediterranean is the largest tourist destination in the world with more than 230 million visitors a year (Obrador Pons, Crang, & Travlou, 2009) Tourism has also had a major physical impact on the coastline with much of it disappearing under concrete and as a result, destroying many valuable natural habitats and wildlife areas. This industry is mainly

concentrated in the coastal areas which receive 30% of international tourist arrivals (WTO, 2011). 25,000km out of the 46,000km coastline is urbanised already reaching a critical limit (*ibid*). Therefore, one can conclude that immense pressure has been placed on the region's rich biodiversity due to this exceptionally rapid growth in tourism and urban development in coastal areas, combined with the abandonment of small scale farming practices (Sundseth, 2009). As a result of urbanisation linked to tourist development, three-quarters of the sand dunes on the Mediterranean coastline from Spain to Sicily have disappeared (WTO, 2011).

2.3. Geomorphology

Geomorphology is the study of landforms such as rivers, hills, plains, beaches, sand dunes and myriad others and the processes that create them (Huggett, 2003). According to the elevation above sea level the overall distribution of the land surface is demonstrated (Gregory, 2010). Geomorphic processes sculpt the Earth's landscape and these vary with the position on the Earth and with time due to climatic conditions (P.Anderson, 2010). Due to change, the Earth's land surface is not static and experiences seasonal changes as well as evolutionary changes such as some coastline progressively advance (Gregory, 2010). There are three chief aspects of landforms in which modern geomorphologists study- form, process and history (Huggett, 2003). The upward and downward movement of sea level has influenced the shaping of many coastlines. However, a range of morphogenic factors have shaped coastal landforms. These include geology which determines the pattern of the rock, climatic factors influencing the wind and wave regimes as well as conditioning coastal vegetation and fauna (Bird, 2008). These produce features ranging from salt marshes, stabilised dunes, shelly beaches and coral reefs (*ibid*).

As uplift takes place, new topography is gradually worn down by geomorphic processes. In many cases uplift and denudation take place at the same time leading to a different model of landscape evolution (Huggett, 2003). As a result of the different combinations of uplift and denudation rates three main slope forms evolve. Hillslopes are bounded by channels and hilltops are convex upward, with a rounded shape and mantled by a layer of soil or mobile regolith (P.Anderson, 2010). This

occurs when the uplift rate exceeds the denudation rate (Huggett, 2003). The rock will undergo chemical and mechanical weathering processes which will result in weakened and broken rock (P.Anderson, 2010). This material is then transported downhill by hillslope processes either through creep or at a much faster rate by landsliding. When uplift and denudation rates match one another a straight slope is formed, leaving the third concave slope as a result of the denudation rate exceeding the uplift rate (Huggett, 2003). Streams at the base of hillslopes receive water and sediment. The entire terrestrial land is bounded by a coastline just as streams bound hillslopes. Unlike those landforms based on interplay of erosion rates and uplift rates, valley-side shape depends on slope material and the nature of slope-eroding processes (Huggett, 2003). Due to global sea level change, local tectonics raises or subsides rock. As a result of coastal erosion or deposition through wave action, this zone of intersection between land and sea is continuously changing (P.Anderson, 2010). Wind erodes rock but also deposits sediment generating recognisable landforms.

The internal engine of the Earth drives plate tectonics which are responsible for the broadest features of the Earth's surface (P.Anderson, 2010). The primary determinants of the level of geomorphic activity in the landscape are slopes both of rivers and hills. There is also the need to know the climate history to understand how the landscape responds to climate change (P.Anderson, 2010).

2.3.1 Geodiversity

Through the interaction of biodiversity and the built environment, geodiversity links people, landscapes and their culture. Geodiversity is best described as:

“the variety geological environments, phenomena and active processes that make landscapes, rocks, minerals, fossils, soils and other superficial deposits which provide the framework for life on Earth” (Stanley, 2000).

The importance of geodiversity is increasing and is seen as essential support to biodiversity and cultural conservation programs. Geodiversity shapes the landscape

around us influencing habitats and species with an educational value to it, allowing one to understand the evolution and history of the Earth and to interpret present and future processes through the reconstruction of the past (Geoconservation.com, 2011).

2.3.2. Geomorphology of the Maltese Islands

Although Malta is an island of simplicity, it is found within a region of complex geomorphology (Anderson & Ewan, *The world: a representative Mediterranean landform*, 1997). The Maltese rock is relatively young with its oldest rock less than 30 million years old (Rix, 2010). It is of Tertiary age, mainly Oligo-Miocene limestone, calcareous sandstones and clays, composed almost entirely of marine sedimentary (Cassar, 2010). The five main rock types are (in order of decreasing age):

- Lower Coralline Limestone which is exposed to a thickness of 140m and is the oldest exposed rock type in the Maltese Islands (Schembri, 1993).
- Globigerina Limestone forms a gently rolling and flatter landscape (Cassar, 2010) with a thickness ranging from 23m to 207m (Schembri, 1993).
- Blue Clay which acts as an aquitard, is exposed to a thickness of up to 65m and often forms clay taluses comprising a rolling landscape (Azzopardi, 2002).
- Greensand has a thickness of 12m (Schembri, 1993).
- Upper Coralline Limestone deposition stopped when the seabed rose above the sea level some 10 million years ago and presently form a thickness of 162m (Azzopardi, 2002).

Globigerina limestone is exposed on the central and southern region forming a gently rolling, flatter landscape. On the other hand, the Rabat/Dingli uplands and the rest of the north-west retain much of the younger strata forming high cliffs (Schembri, 1993). The Maltese islands have several types of coasts (refer to Map 1). Coralline limestone plateaus form the highest areas, Blue clay slopes occur at coastal areas and in valleys, Rdm or undercliff areas are found where blue clay slopes descend steeply to the sea beneath the UCL cliffs (Cassar, 2010). Flat floored basins are present such as the Pwales valley. Globigerina limestone hills and plains include large areas of gently sloping land (Magri, 2006). The formation of the characteristic Maltese landscape is a result of erosion of these different rock types. The southwest of the Maltese Islands

are bounded by sheer cliffs composed by Lower Coralline Limestone. Similarly, massive cliffs and limestone platforms of karstic topography are formed by Upper Coralline Limestone (Cassar, 2010). Globigerina Limestone forms a broad rolling landscape and is the most extensive exposed rock formation (Azzopardi, 2002). This is mainly evident in the eastern region of Malta and in Gozo is present in the southern and western sectors (*ibid*). Coastal areas are shaped by Blue Clay taluses which form broad slopes with the presence of the younger strata (Cassar, 2010).

Climate is also a fundamental contributor to shaping geomorphologic features. The Mediterranean Basin is characterised by hot dry summers and humid, cold wet winters, however still experiencing sudden torrential downpours or bouts of high wind (Sundseth, 2009). This climate is generally moderate lacking extremes and is bordering on semi-arid, however it is best described as biseasonal with influences from its surrounding sea and land. The monthly mean air temperature ranges from 12.4 degrees C during winter to 23.6 degrees C during summer with an average rainfall of 553.1 mm (Met Office). evapotranspiration accounts for 70%-80% of the total annual precipitation leaving only 16% of rainfall infiltration into the substratum which can be used by vegetation (Cassar, 2010). With March and December having the highest frequency of gale force winds, the Maltese Islands have an annual winds speed of 8.8knots (Met Office). However, January has a mean wind gust of 47 knots (*ibid*).

2.3.3. *Wied (valleys) and Rdum (rocky hillslopes)*

The rdum and wied systems are topographic features of ecological importance. As a result of the humid temperature and semi-arid climates the wied are a predominant feature of the geomorphology of Maltese Island as they cover much of the land. These features appear as a hybrid between the river valley which developed as a result of the more humid climates to the north and the wadi as a result of the more arid landscapes found in the south.

The wied are a typical characteristic not just of Malta but of the whole Mediterranean region as the climate itself is a combination of the northern and southern climates. Through palaeoclimatic records of Malta, evidence shows the

widien formation during the time of high rainfall intensities with some evidence of colluvial silts in the same period. These widien form a pattern which comprises a network of dry valleys and small rivers (refer to figure 2.3) (Azzopardi, 2002). Eroded terraces in the valleys have been identified in some of the southwest flowing widien. Such evidence can be seen in Wied Zurrieq (Vossmerbaumer 1972). Through Vossmerbaumer's detailed analysis of wied orientation it has been indicated that an earlier network established by tectonic activity resulted in the current pattern of valleys. These water formed channels are a result of either tectonic movement or stream erosion during a previous and much wetter climatic regime. The widien presently carry water along their courses only during the rainy seasons. Otherwise, they are just dry valleys. However, a few widien do maintain a water flow in the form of springs which also help support one of the richest habitats on the islands (Anderson & Ewan, 1997). On the other hand, the quasi-vertical rock faces as well as the boulder scree and other eroded debris from the rock face are a result of either erosion or tectonic activity and these are comprised by the rdum. The rdum formation offer shelter and thus affords a habitat for many species of flora and fauna (Cassar, 2010).

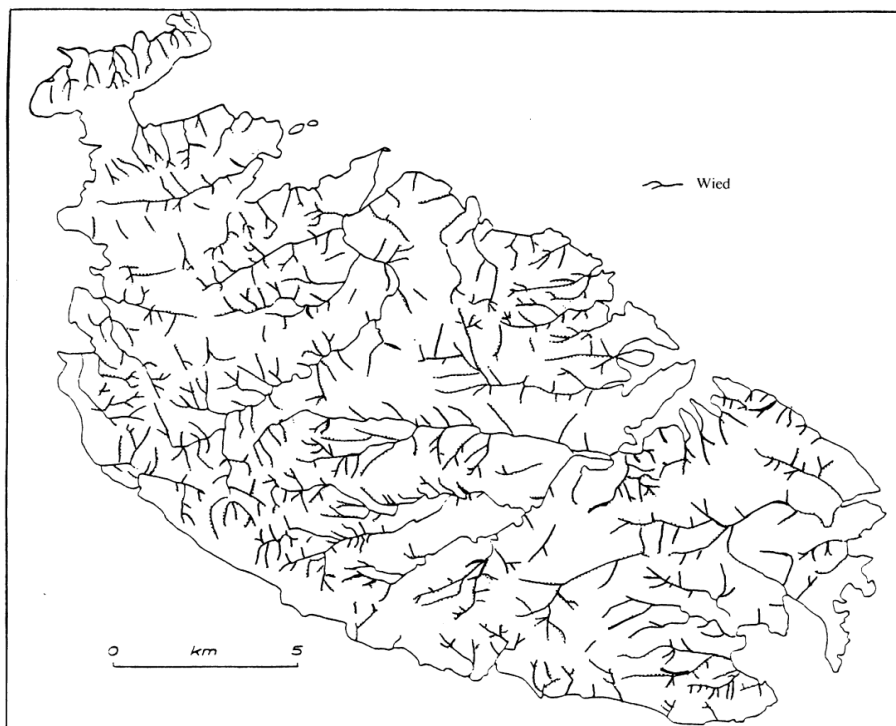


Figure 2.3: Showing the widien present in Malta. Source: (Anderson & Schembri, 1997).

2.4. Evolution of Landscape

Archaeological evidence shows early settlers and has proved that the Mediterranean Basin, also known as the cradle of civilization, is home to some of the globe's oldest cultures. Resources in the region were exploited by humans colonizing these various locations in the Mediterranean. The region soon became a station to various people and societies as the agricultural revolution began to form and as a result of food surplus requirements. Each of these changes is driven by the widespread adoption of cultural and technological innovations (Yohay & Zev, 2002).

More often than not, through revolution, man has shaped the environment and changed its natural surroundings. As anthropogenic activities or natural occurring processes shape geomorphologic features into new a new profile, biodiversity found within these environments is forced to adapt to these changes otherwise they will become endangered (refer to figure 2.4). The construction boom helped to increase Malta's urban area from 4% of the total land area in 1956 to 23% 2005 (Dolceta, 2012). A particularly intimate relationship has been created between the environment and its inhabitants as a result of the islands' unusually long history of human occupation (Role).

As people inhabit the shores the coastline and surrounding physical environments face common environmental challenges. With a constant demand for land resulting in ever-increasing human pressures, vast areas have been modified (Cassar, 2010). Population growth has also accelerated by improvements in public transport making remote areas more accessible. After the Second World War, families moved to the countryside and abandoned the harbour regions. Post war also brought about commercial opportunities further adding pressure on a shrinking countryside. Landscape evolution is a result of the cultural evolutionary process and the rapidly expanding urban-industrial and agro-industrial landscapes (Yohay & Zev, 2002). Rapid economic development led to insensitive urban development which introduced the need for adequate national environmental and planning policies. This post-war revolution contributed to environmental degradation and increased the urban footprint. Disturbed ground has become the most widespread habitat across the islands due to the high level of human impact (Cassar, 2010). There has been an increase in the relationship between ecology and the environment in which ecologists rely on the concept of ecosystem and the concept of landscape (Yohay &

Zev, 2002). As a consequence of all this development, there has been the degradation of natural resources and conflict between users (MEPA, 2002).

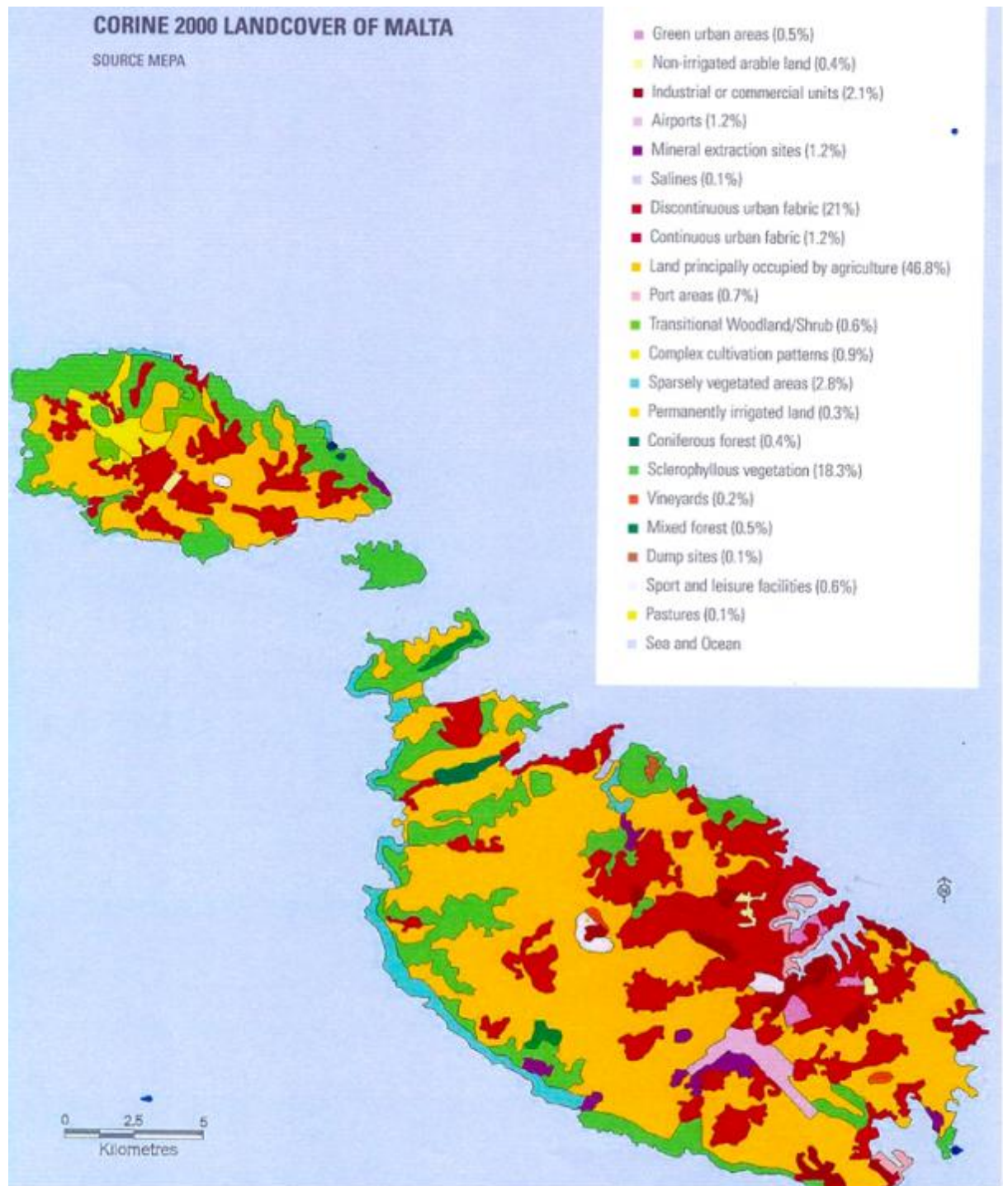


Figure 2.4: Showing the Land Cover of Malta. Source: Dolceta, 2012 online at <http://www.dolceta.eu/malta/Mod5/Population-Density-Land-Use-and.html>, 2012.

2.4.1 Population Density

Malta having one of the highest population densities of 1,282 per sq km, in Europe brought about a substantial increase in urban land-cover with significant problems on the overall balance between urban and rural regions. The littoral is the area which has most evidence of human pressure. This is mainly due to the Maltese Islands attracting a high rate of tourists with many coastal areas becoming more accessible to road construction and more built up. Numerous coastal habitats have declines over the centuries as a result of intensive agriculture, and an assortment of installations of an industrial, economic/commercial and military nature. Only 2.4 % of the islands' coastline consists of sandy beaches out of a total of 190kms and these have been heavily impacted upon.

2.4.2.. Clearance of land

Due to the long history of human occupation and recent economic and population trends, the Maltese Islands are vulnerable to a variety of environmental problems (Role). Early settlers cleared the natural woodland and other vegetation which modified the existing landscape (Schembri, 1993). This clearance created a niche space for new species to establish themselves. However it also brought about a loss of existing ecotopes and biotic communities. The landscape continued to be modified during the last century with pressures becoming greater (Cassar, 2010). The clearance of natural habitats for agriculture and building development, dumping of domestic and building waste, as well as quarrying were the main threats encountered (*ibid*).

2.4.3. Dumping sites

The two dumping sites in Maghtab and Xaghra that there were in Malta and Gozo posed serious environmental problems especially since both were relatively close to the coast. These dumping sites were not only visually offensive, but clouds of noxious, unhealthy fumes were produced as the rubbish was burnt. In the long run there was possibility of serious contamination problems as poisonous chemicals would seep into the aquifers (Cassar, 2010). Maghtab rubbish dump was closed in April 2004 as it was a major environmental milestone for the country (WasteServ, 2012). The Qortin landfill, which has also been closed since 2004, will now be

planted with a significant amount of trees as part of the eco-Gozo action plan (eco Gozo, 2012).

2.4.4. Quarrying

Limestone being the only valuable resource within the Maltese Islands is extensively quarried. Globigerina Limestone is used as building material and the coralline limestones are used as composite for concrete and road construction (Schembri, 1993). Globigerina Limestone quarries in Gozo amount to 17.8871 hectares, while that by coralline limestone quarries is around 6.9038 hectares of which are of hardly any significance compared to the total quarried area in Malta (Cassar, 2010). Old quarries are sometimes reclaimed for agricultural purpose. However, a relatively high number are left abandoned without reclamation as they would have been over worked. However, quarried land area is extending at a fast rate as new sites are being excavated and sometimes are in ecologically sensitive localities. Some quarries in Gozo are sited or near areas of ecological importance. Such an example being in Dwejra, where the quarries are a threat to the area's conservation status (*ibid*). Little importance is given to agricultural land and natural habitats when the building industry is involved in terms of land-use which is the most significant environmental offenders. Particulate contamination which is a potential health risk, building waste and debris accumulation contribute to problems of an environmental management nature.

2.4.5. Soil erosion

Human encroachment and activity are one of the main contributors to soil cover erosion which has caused a shift from cultivated land to bare rocky areas in the north of Malta and some plateaux in Gozo. These areas show that at one time they were used for cultivation purposes as they are enclosed within a network of rubble walls. Heavy rainfall is another factor contributing to soil loss and as a consequence of runoff, the resultant topography makes it difficult to access remote areas by agricultural machinery. This in return leads to agricultural abandonment as farming practice becomes less economical and more labour-intensive.

2.5. Geoconservation

Higher income, an increase in social benefits as well as more employment from younger generation rather than cultivating land full-time, has led to more land abandonment especially in Gozo (Cassar, 2010). The effect of land abandonment varies according to several factors such the availability of water resources, soil type and topographic characteristics which all influence the landscape (Role). Colonization of the land by vegetation succession and species composition are all influenced by factors such as exposure, water, soil conditions and other environmental circumstances (Cassar, 2010).

Geoconservation concerns the managing and protecting of the non-living natural environment in which both geological and geomorphological conservation as well as Earth heritage conservation is considered (JNCC, 2012). The geological aspect protects rocks, minerals and fossils whereas the geomorphological conservation covers the landforms and landscape-shaping processes. Geoconservation recognises, protects and manages sites and landscapes identified as important for their geomorphological and geological interest. It is a vital part of nature conservation as the preservation of rocks is necessary for earth science and education (IUGS, 2012). In comparison to the strong concern towards biodiversity conservation, little attention has been paid to it (*ibid*).

In Europe, The EC Bird's Directive and Habitat's Directive created sites such as the Special Protection Areas (SPAs) for Birds and Special Areas of Conservation (SACs) which are of European importance but which have nothing to do with conservation of geological heritage (JNCC 2012). Public awareness of all aspects of nature should be increased through protected areas (Brilha, 2002). As a result visitors receiving enough information will be just as interested in rocks as they seem to be in plants (*ibid*). Our perception of the need to protect the natural environment has increased through the awareness of reports about pollution, the extinction of species and the disappearing of rainforests (Ellis et al, 1996). Climate, geology and landscape all affect the distribution of habitats, plants and animals. Geology and landscape are not only a fundamental part of the natural world but they have a profound influence on society and civilisation. The underlying rocks, soil and landform are intimately related to the use of land for building homes and cities as well as for agriculture, forestry, mining and quarrying.

ProGEO's main objectives are to promote the conservation of Europe's rich heritage of landscape, rock, fossil and mineral sites, to advise and involve our countries and those in Europe responsible for protecting our Earth heritage, to organise and participate in research as well as to achieve an integrated approach to nature conservation through a holistic approach (ProGEO, 2012). There are currently two ongoing ProGEO projects. The Manual Project aims at a review in different European countries on the present situation on geoconservation (*ibid*). The GEOSITES Project was started by IUGS in 1996, supported by UNESCO and decided to establish a worldwide catalogue of geological sites of international importance (*ibid*).

2.5.1. Geoconservation in Malta

There are significant geo-heritage assets in the Maltese Islands these being karstic landscapes, sheer coastal cliffs/ escarpments, rdm, horst/graben system, shore platforms, solution subsidence structures and raised beaches. Malta is very advanced in its progress to designate terrestrial sites under the EC Habitats Directive with a sufficiency index of 92.64% as at June 2008 (MEPA, 2008). On the other hand, although Malta has a varied geomorphology with significant importance, the Island hosts no formal geopark. However, there are scheduling mechanisms that protect geo-features such as the Sites of Scientific Importance, Areas of Ecological Importance as well as Area of High Landscape Value (Cassar & Conrad).

2.5.2. Geoparks

A geopark is a combined area with geological heritage of international significance (UNESCO, 2011). Geoparks aim for full sustainable development through the protection of national geological heritage. The main aim of a geopark is to support a sustainable management of the resources and territory by creating scientific instruments as well as making geological and geomorphological resources, mapping and guidebooks available (Brilha, 2002). The concept of geoparks combines conservation, education and geotourism through a three-pronged approach

(Geoparks, 2012). National geological sites gain worldwide recognition and importance and profit from the exchange of knowledge, experience and expertise through the exchange of geoparks around the world (Geoparks, 2012). Another goal is to account and characterise the value and relevance on a local, national and international level of geosites (Brilha, 2002). Geoparks involves the local community through activities such as educational tours and resources, geological walking trails, information centres, museums and the creation of local enterprises related to geotourism and geoproducts (Geoparks, 2012). As of January 2012, there a total of 89 Global Geoparks spread across 27 countries (refer to figure 2.5) (UNESCO, 2012). These have been concentrated in China and Europe however the last few years geoparks have spread worldwide so that there are existing Global Geoparks, or active applications to become Global Geoparks on all continents (*ibid*).

‘Geoparks are not just about rocks-they are about people. It is crucial that they get involved. We want to see as many people as possible getting out and enjoying the geology of the area. Our aim is to maximise geotourism (...) for the benefit of the local economy and to help people to understand the evolution of their local landscape’ (Chris Woodley-Stewart, Geopark Manager, North Pennines AONB, United Kingdom).

UNESCO became activated in this area in 1999 when Geoparks were proposed as a UNESCO programme (UNESCO, 2011). Presently, UNESCO gives its support to Global Network of National Geoparks which co-ordinate national Geopark initiatives. UNESCO supports The Global Geopark Network (GGN) which was established in 2004 and through active cooperation between practitioners and experts in geological heritage, a worldwide platform is achieved. It consists of 27 member states such as Australia, UK, Austria, Brazil, China, France, Germany, Greece, and Italy etc with 89 national geoparks.

The European Geoparks Network (EGN) was formed in 2000 and currently consists of 49 European geoparks (refer to figure 2.6) across 19 European countries (OneGeology, 2011). Territories across Europe have been brought together through the network. They share the same aims on promoting geological heritage to the general public, as well as the development of geological tourism in which

sustainable economic development of geopark territories is achieved (European Geoparks Network). Geoparks always mainly promote geology. However the network members via than natural and cultural heritage activate people's interest in geology through a holistic approach. In 2001, a formal agreement between the European Geoparks Network with the Division of Earth Sciences UNESCO was signed. In 2004 another agreement was signed with UNESCO in which responsibility was given to the EGN in order to regulate membership of the UNESCO Global Network of Geoparks in Europe (European Geoparks Network)

In Portugal, although there are five natural monuments with geological relevance, no natural park is dedicated to geology (Brilha, 2002). However, in recent years an effort has been made to study these natural parks and a project is under development in the two natural parks of north-east Portugal (International Duoro Natural Park and Montesinho Natural Park) (*ibid*).

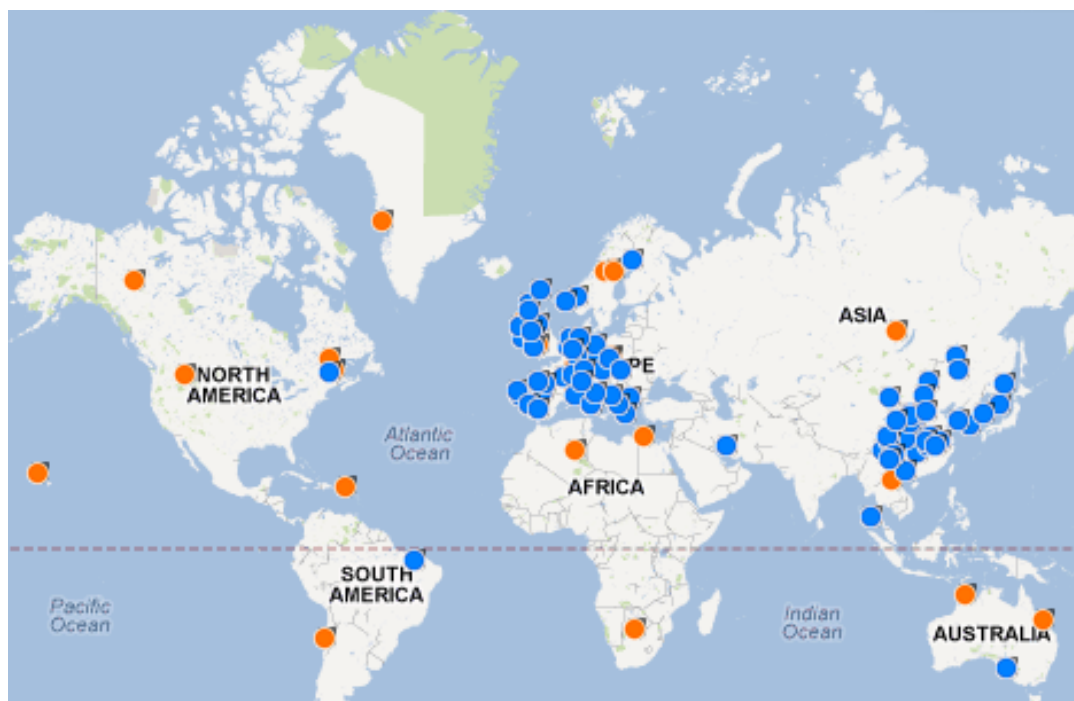


Figure 2.5: Showing the 89 Global Geoparks spread across 27 countries.
Source: OneGeology, 2011. Online: Available at
<http://www.onegeology.org/extra/geodiversity/map.html>

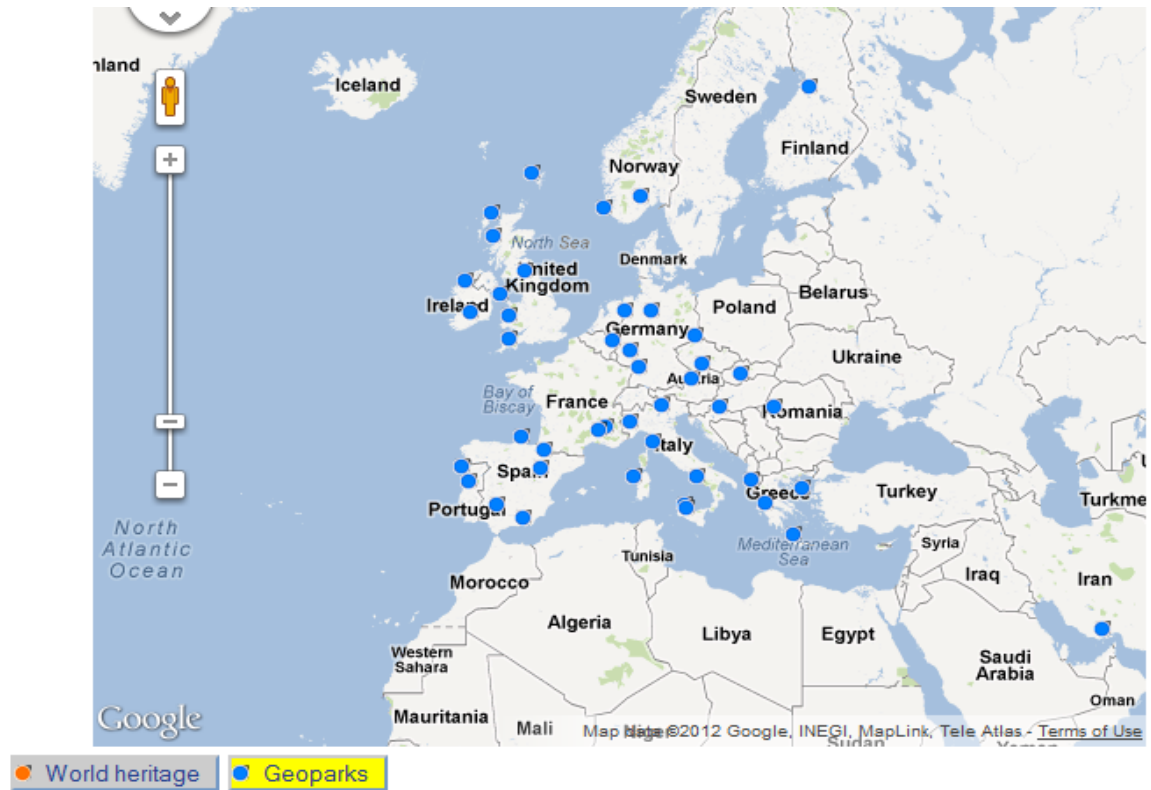


Figure 2.6: Showing the distribution of the 49 Geoparks in Europe across 19 countries. Source: OneGeology 2011. Online: Available at <http://www.onegeology.org/extra/geodiversity/map.html>

2.5.3. Conservation of Geomorphology in tandem with Conservation of Biodiversity

The real nature conservation can only be attained if all natural processes are considered together; most importantly geomorphology is integrated into protected area management at the same level of importance as biodiversity (Brilha, 2002). Abandoned land experiencing ecological succession usually establishes a higher degree of species diversity than those ecologically stable communities nearby (Cassar, 2010). Unfortunately, in spite of international recognition, although the threats to geodiversity are as real as those affecting biodiversity, these are less well known (Brilha, 2002).

The ecosystem approach to land planning and management focuses on the conservation of the biotic components in the system and their processes (Yohay & Zev, 2002). This type of conservation views the entire area as composed of several habitat types rather than actual, specific land parcels (*ibid*). In most ecosystem

models, anthropogenic elements are viewed in the land as unwanted, disturbing and disrupting nature's harmony (*ibid*). Geological heritage considers the importance of the site, its use and need to conserve it (Brilha, 2002). It is of significant importance to incorporate geomorphology into conservation policies at the same level as biodiversity (refer to figure 2.7). This is due to the fact that all geological features are vulnerable to obvious threats such as inappropriate site development however also threatened by the encroachment of vegetation, natural weathering and general deterioration (OneGeology, 2011).

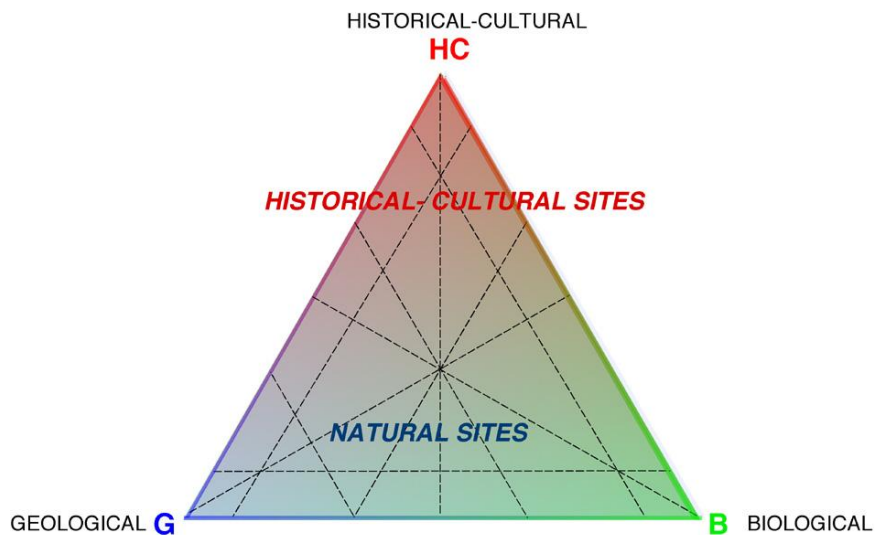


Figure 2.7.: Showing geological heritage, an essential part of the integral management of World heritage in protected sites. Source: IUGS, 2012.

2.5.4. Results of Conservation

The importance of geological conservation heritage has been recognised by a number of international institutions those being: UNESCO and the International Union of Geological Sciences and in Europe the European Association for the Conservation of the Geological Heritage, ProGEO, promotes and integrated

geoconservation strategy. Scotland, Canada and England recognise the importance of geology in their protected area management plans (Brilha, 2002). The Mediterranean Region has proven to have limited management on geo-conservation and with little integration within countries and across countries (Cassar & Conrad). Since tourism is an important sector in the Mediterranean Region, there should be an integrated tourism product such as the diversification of tourism away from Sun-Sea-Sand (*ibid*). The International Geoscience Program (IGCP) has financially supported international research teams through 400 projects on geological problems of global importance (UNESCO, 2012). The IGCP financially supports 30 projects per year with funding levels ranging from 5,000 to 10,000 USD (*ibid*). In 2012, a total of 29 projects received continued support with 5 being new proposals (UNESCO, 2012).

Chapter 3

Site/s

Description

Chapter 3

Site/s Description

3.0. Overview

All the Sites of Community Importance (SCIs) in Malta are branched out in an uneven distribution and thus be divided by those found in the northern, southern and eastern region (table 3.1). The southern part of the island binds a broad variety of SCIs of significant importance with a total of 7 sites in which these all overlap and extend throughout the entire coastline. On the other hand, the north abides 12 more isolated SCIs and another 2 found in the east (figure 3.1). Each SCI varies from one another, some being of terrestrial importance and others of marine or coastal concern. However, some sites might overlap with a terrestrial and marine importance as the geomorphology is studied.

Cardinal Direction	SCIs
North	Ramla tat-Torri/ Rdum tal-Madonna Area
	L-Ghadira Area
	Wied il-Mizieb
	L-Imgiebah/ Tal-Mignuna Area
	Il-Gzejjer ta' San Pawl/ Selmunett
	Xaghra tal-Kortin
	Simar (San Pawl il-Bahar)
	Il-Ballut tal-Wardija (San Pawl il-Bahar)
	Is-Salini
	L-Ghadira s-Safra
	Pembroke Area
	South
Rdumijiet ta' Malta: ir-Ramla tac-Cirkewwa sa il-Ponta ta' Benghajsa	
Ghar ta' L-Iburdan	
Rdumijiet ta' Malta: Ras il-Pellegrin sa Ix-Xaqqa	
Buskett- Girgenti	
Rdumijiet ta' Malta: Ix-Xaqqa sa Wied Moqbol	
Il-Maqluba (Qrendi)	
East	Ghar Dalam
	Il-Ballut (Marsaxlokk)

Table 3.1: The distribution and names of the SCIs in Malta. Source: Composed by author.

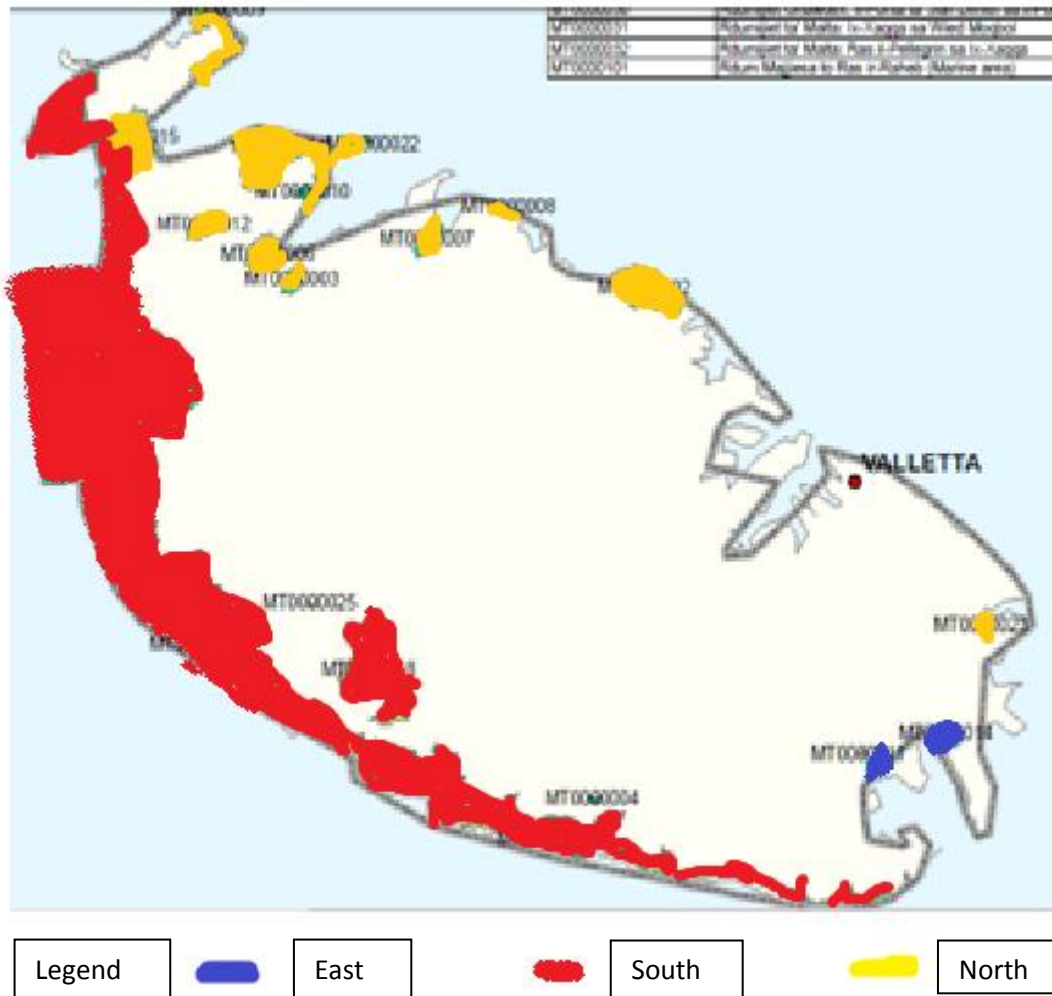


Figure 3.1: Sites of Community Importance on the main island, Malta. Source: Natura 2000 edited by author.

3.1. Introduction to Malta

Malta Plateau is located on a shallow shelf extending from the south of Sicily to the coast of North Africa and forms part of a submarine ridge (Schembri, 1997). There are two main series of faults in the Maltese Islands which trend from NE-SW and NW-SE. The NE-SW consists of the Great Fault which is on the main island of Malta (Pedley, House, & Waugh, 1976). This Fault bisects Malta from Fomm ir-Rih on the southwest coast, to Madliena on the northeast coast (Azzopardi, 2002). The Maghlaq Fault which is situated along the southern coast of Malta is of importance to the NW-SE trending faults as this has been responsible for the movement of the islet of Filfla to sea level (Schembri, 1993). The other member of the Great Fault is the South Gozo Fault which crosses from Ras il-Qala on the east coast to Mgarr ix-Xini on the southeast (Schembri, 1997). As a result of block faulting, a sequence of

horsts and grabens has been introduced between these two master faults, which proceedings from the Great Fault are: the Bingemma Basin, Wardija Ridge, Pwales Valley, Bajda Ridge, Mistra Valley, Mellieha Ridge, Ghadira Valley and Marfa Ridge (Schembri, 1993). The south Comino Channel which separates Malta from Comino is the next graben in the sequence however this is inundated by seawater (*ibid*). Comino is then the next highest part of the next horst above sea level, with the next graben being the north Comino channel under seawater.

The development of coastal scenery around the islands is influenced by the presence of partially or totally submerged karst caves (MEPA, 2012). Paskoff and Trenhaile (1987) mention the semicircular coves or circular structures mainly evident in the southern coast of Malta which are related to solution of limestone or also wave action. There are two types of cliffs found along the Maltese archipelago. These are the vertical plunging cliffs and the rdum or coastal scree cliffs (MEPA, 2012). On the other hand the north-east side of Malta and north of Gozo lack cliff formation with low rocky coastlines instead.

The Maltese Islands have an impoverished array of native, terrestrial, marine and freshwater species. A number of plants and animals are endemic to the Maltese Islands and found nowhere else in the world (Schembri, 1993). Maltese ecosystems range from woodland which are characterized by Holm Oak *Quercus ilex* and Aleppo Pine *Pinus halepensis* (MEPA, 2012) to maquis which develops in relatively inaccessible sites on the sides of steep valleys and at the foot of inland cliffs characterised by a number of small shrubs (Schembri, 1993). On the other hand, garrigue which is characterised by low-growing shrubs, phrygana and steppe are found on karstic plateaux, in more exposed areas where soils are shallow (Cassar, 2010). Coastal habitats are those found in those areas where the land meets the sea and these include the saline marshlands, dunal systems within sandy beaches and rocky shores (Schembri, 1993). Wetlands on the Maltese Islands are scarce however these characterize temporary watercourses, a few permanent springs, rainwater rock-pools and saline marshlands (Cassar, 2010). Rupestral communities grow on cliff faces and boulder shores as well as caves which are inhabited by organisms with a very restricted distribution such as bats (MEPA, 2012). The last community type, freshwater communities, are seasonal are therefore rapidly dry up during the hot

period. Karstic terrain is characterised by rainwater pools, harbouring a distinct biota in which these species exploit the rock depression filled with rainwater during the brief, wet seasons (Cassar, 2010). These natural freshwater pools house many freshwater species which are overall rare in the Maltese Islands (Lanfranco & Grillas, 2012). The freshwater species found in these habitats are extremely rare to the Maltese Islands (Schembri, 1993). However, the bulk of these species live within wadien watercourses filled up during the wet season (MEPA, 2012).

3.2. Sites of Community Importance in the North

The northern region retains much of the younger strata on the uplands. Globigerina forms a broad rolling landscape consisting of the most extensive exposed rock formation.

3.2.1 Ramla tat-Torri/Rdum tal-Madonna Area

This area represents the best sand dune community of Malta (refer to plate 3.1) and is home to the endemic Maltese sand broomrape (MEPA, 2012). It also supports large colonies of threatened sea-birds being one of the most important bird areas in the Maltese Islands. A variety of coastal habitats are found in this Natura 2000 site with the cliff faces offering habitat to a number of plants such as the Maltese salt tree. A substantial proportion of this area is characterised by coastal cliffs and boulder scree constituting the largest breeding site for the Yelkouan Shearwater (MEPA, 2012). An EU-funded project has been focusing on this site whose aim was to conserve the bird species.



Plate 3.1: Ramla tat-Torri. Source: Google Imagery, 2012.

3.2.2. L-Ghadira Area

Besides the importance of a sandy beach, Ghadira Nature Reserve was created through the driving force of BirdLife Malta (BirdLife Malta, 2012). L-Ghadira area (6 hectares) encloses a wetland and a saltmarsh also hosting a variety of animal and plant life bringing it to extreme ecological importance (refer to plate 3.2). In 1978, it was declared a bird sanctuary through scientific data presented to the Government by BirdLife (BirdLife Malta, 2012). Over 200 species have been recorded in the reserve and as a result, hunting and trapping has been banned within 500metres of the site, however the reserve still encounters break-ins.



Plate 3.2: L-Ghadira Area. Source: Google Imagery, 2012.

3.2.3. Wied il-Mizieb

This site forms part of the valley sides of Wied il-Mizieb and Wied tax-Xaqrani in which it comprises a rocky plateau (refer to plate 3.3). This area is home to the largest population of the National Tree- *Tetraclinis articulata* (Gharghar) with about 150 specimens and has been protected since 2001 as a Tree Protected Area by Mepa (Malta Environment and Planning Authority , 2011). There are several plant communities including phrygana and pre-desert scrub habitat types. Indigenous species are also found in the soil at 10-30cm depth under the tree (Malta Environment and Planning Authority , 2011).



Plate 3.3: Wied il-Mizieb. Source: Google Imagery, 2012.

3.2.4. *L-Imgiebah/ Tal-Mignuna Area*

Wied L-imgiebah hosts one of the only four forest remnants in the Maltese Islands (refer to plate 3.4) (Schembri, 2003). This site is habitat to historical trees having an antiquarian importance mainly based on the very old holm oak trees. Due to shading abilities of the oaks' crowns, there is limited undergrowth and humid conditions as a result of the forest area characterised by a much closed canopy (MEPA, 2012). Consequently there is a rich leaf litter with slime moulds and invertebrates in the forest undergrowth species. Besides being a Natura 2000 SPA, in 2011 MEPA declared this site as a Tree Protected Area.



Plate 3.4: L-Imgiebah. Source: Google Imagery, 2012.

3.2.5. *Il-Gzejjer ta' San Pawl/ Selmunett*

St Paul's Islands, in fact a single land-mass, has some interesting geology features with the second part of the island being a quartz island with huge quartz deposits and crystals (refer to plate 3.5). St Pauls Islands have been designated as a SPA since 1986 (MEPA, 2007). Studies show that the biodiversity on the Islands, especially the lizard population, are suffering from the proliferation of rats (MEPA, 2007). MEPA was assisted on a project to restore the habitat for the endemic lizard which helped the population to recover and as a result the natural vegetation recovered significantly (MEPA, 2007).



Plate 3.5: Il-Gzejjer ta'San Pawl. Source: Google Imagery, 2012.

3.2.6. Xaghra tal-Kortin

This site hosts a mosaic of habitats including the predominant boulder scree and garrigue (refer to plate 3.6). This typical boulder scree coastline offers habitat to flora which is barely touched as it is in unreachable areas. The commonest of the Maltese endemics forms part of the cliffs species. Other species which have a restricted distribution in the Maltese Islands, such as the black bryony- *Dioscorea communis*, are present in the cliffs and associated boulder scree (Schembri and Lanfranco, 1996). A small pebble beach at Il-Qala tal-Mistra, is commonly covered by seagrass banquettes. These support an interesting community of marine and terrestrial species including spiders, snails, amphipods etc (MEPA, 2012).



Plate 3.6: Xaghra tal-Kortin. Source: Google Imagery, 2012

3.2.7. Simar (*San Pawl il-Bahar*)

This site was a neglected and degraded marsh used largely as a dump up until the 1980s (BirdLife Malta, 2012). BirdLife Malta converted Simar into a sanctuary for wildlife in the early 1990s in which nature now thrives and flourishes in full protection (refer to plate 3.7) (BirdLife Malta, 2012). With reedbed, open pools and canals, hundreds of trees planted over the years and an olive grove, Simar is a mosaic of habitats (BirdLife Malta, 2012). As a result, numerous forms of native wildlife especially birds, have been attracted to these habitats.



Plate 3.7: Simar. Source: Google Imagery, 2012.

3.2.8. *Il-Ballut tal-Wardija* (*San Pawl il-Bahar*)

The northern ridge is interrupted by a series of valley systems as a result of a combination of tectonic movement and karstic processes (refer to plate 3.8) (Schembri 1993). *Il-Ballut tal-Wardija* is dominated by a forest remnant of holm oak trees covering 8% of the area, supporting, possibly, the oldest population of trees, some dating back at least nine hundred years (MEPA, 2012). This site hosts one of the four remaining oak forest remnants in the Maltese Islands and as a consequence has been a tree reserve since 2001 (*ibid*). Present on site is a supply of flowing freshwater coming from permanent springs.



Plate 3.8: Il-Ballut tal-Wardija. Source: Google Imagery, 2012.

3.2.9. *Is-Salini*

Is-Salini is mostly known for its salt pans; however, it is the largest of the remaining coastal marshes of the Maltese Islands being home to an array of rare habitats and species (refer to plate 3.9) (Schembri, 1993). The canal running to the left and right of the salt pans is the only brackish water fish endemic to the Maltese Islands, hosting one of the three populations of the Maltese killifish- *Aphanius fasciatus* (MEPA, 2012). The marsh habitat is continuously being supplied with freshwater originating from a complex of valley systems that drain into the area forming an estuary with salt marsh and freshwater vegetation. Along the border of the salt marsh there are pockets of garrigue remnants.



Plate 3.9: Is-Salini. Source: Google Imagery, 2012.

3.2.10. *L-Ghadira s-Safra*

This coastal wetland is in the north east of Malta and covers 0.8 hectares of land (refer to plate 3.10). In the dry season sea water replenishes the rock pools found in this seasonal, brackish water environment. During the wet seasons, freshwater fills up the pools becoming a good habitat for freshwater species that tolerate seawater influence. This makes L-Ghadria s-Safra a unique wetland supporting very rare, numerous protected flora and fauna.



Plate 3.10: L-Ghadira s-Safra. Source: Google Imagery, 2012.

3.2.11. Pembroke Area

This area covers 97 hectares of land and is characterised by karstified rocky terrain (refer to plate 3.11) (Nature Trust Malta, 2012). This has been colonised by a complex mosaic vegetation cover typical of grass steppe, rocky steppe and low garrigue communities. The garrigue found in Pembroke are almost the most species-rich found in the Maltese Islands (Nature Trust Malta, 2012). There is a remnant climax shrubland framework in which many areas are superimposed by various stages of secondary ecological succession marking different episodes of disturbance (Nature Trust Malta, 2012). Temporary rainwater rockpools and pockets of woodland (mainly small woodlots of the archaeophytic maquis and afforestation areas) colonize most of the site breaking the steppe/garrigue mosaic.



Plate 3.11: Pembroke Area. Source: Google Imagery, 2012.

3.2.12. *Il-Maghqlub tal-Bahar (Marsascala)*

This site is a small saline marshland with salt-tolerant marsh communities supported by a brackish water pool habitat to critically endangered species such as the Maltese killfish (refer to plate 3.12) (MEPA, 2012). The freshwater from the surrounding fields and the rainwater entering the pool that mixes with the seawater entering the connection under the road, results in the brackish water. This is one of the two only remaining salt marshes in the south of Malta and supports a good community of salt-tolerant species and wetland plants (Schembri, 1997)



Plate 3.12: Il-Maghqlub tal-Bahar. Source: Google Imagery, 2012.

3.3. Sites of Community Importance in the South

The south is bound by sheer cliffs of Lower Coralline Limestone with Upper Coralline Limestone forming massive cliffs and limestone platforms of karstic topography.

3.3.1. *Rdum Majjiesa to Ras ir-Raheb (Marine Area)*

Rdum Majjiesa to Ras ir-Raheb is along the northwest coast with a length of around 11km and a total area of 9520 m² (refer to plates 3.13 and 3.14) (Schembri P. J., University of Malta, 2008). Along this coastline there are several bays and inlets with Blue Clay taluses and semi-circular coves as well as seacliffs. This site supports a representative selection of all major biotopes occurring around the Maltese Islands, hosting a rich and diverse array of flora and fauna (Schembri P. J., University of Malta, 2008). *Posodonia* and various meadows occur in the area each supporting rich

accumulation of species many of conservation and economic importance. Hard substrata throughout the area are dominated by algae especially on submarine cliff faces and at the entrance of sea caves (Schembri P. J., University of Malta, 2008). Extensive areas of bare sand support a rich epifauna and a large variety of burrowing species seeking food and refuge in the sand.

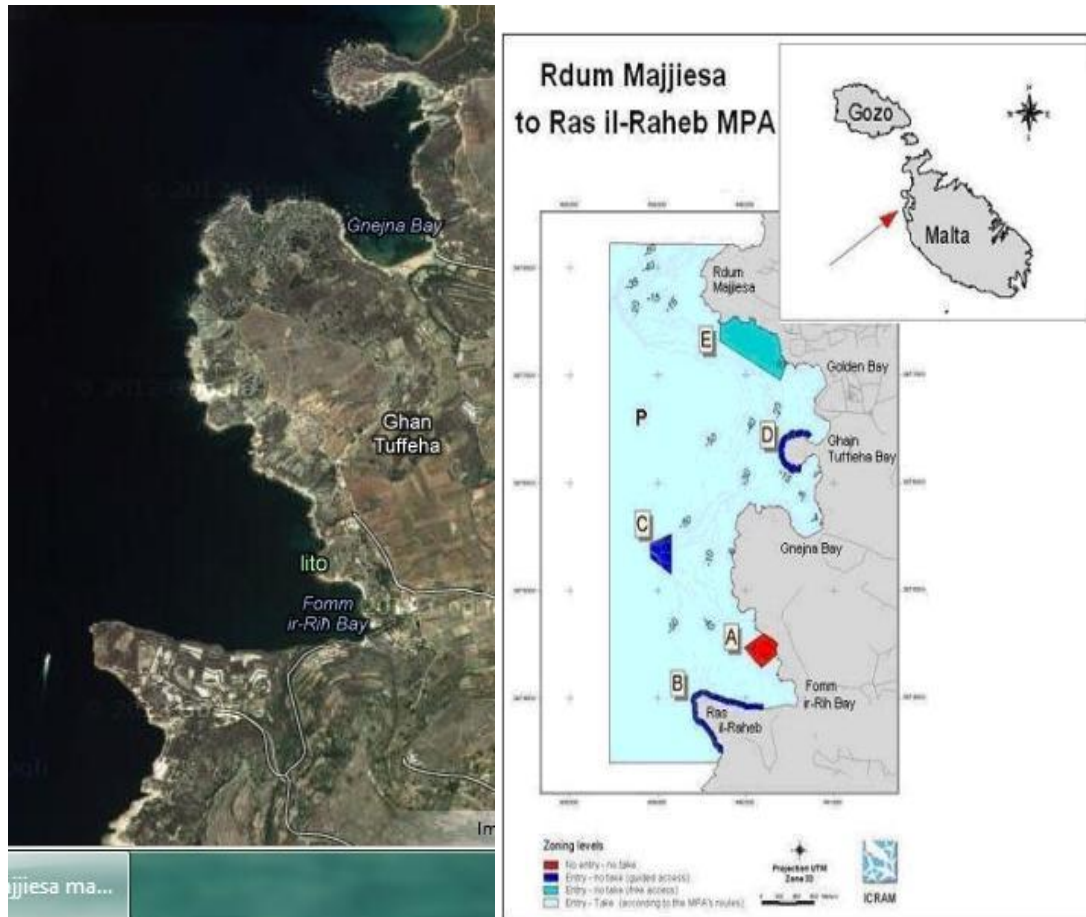


Plate 3.13: Rđum Majjiesa to Ras is-Raheb. Source: Google imagery, 2012.

Plate 3.14: Source: University of Malta, 2008.

3.3.2. Rđumijiet ta' Malta: ir-Ramla tac-Cirkewwa sa il-Ponta ta' Bengħajsa

These coastal cliffs stretch along the coast from Birzebbuga to Cirkewwa and Mellieħa (refer to plates 3.15 and 3.16). A series of Mediterranean dry valley systems (widien) with a seasonal watercourse completely drying up in the dry period with the influence of saline conditions, characterise this site. Much of the coastal cliffs are symbolised by coastal clay taluses which specifically in Ghajn Tuffieħa/Fomm ir-Riħ area are home to a rare species called *Fagonia* (Schembri,

1997). One of the few existing sand dunes in the Maltese Islands are present in one of the number of sandy beaches found in the area. Two important bird species have their habitats in the stretch of the cliffs between Xaqqa and Wied Moqbol. Migratory and wintering bird species use the valleys found between the cliffs as feeding and resting grounds (MEPA, 2012).

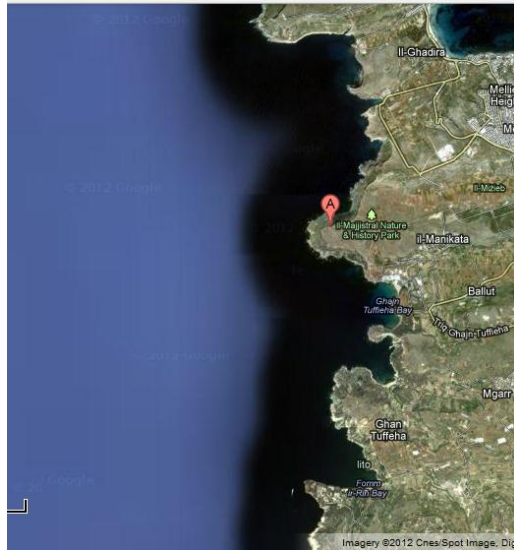


Plate 3.15 and 3.16: Rđum Majjiesa to Ras ir-Raheb. Source: Google Imagery, 2012.

3.3.3. *Ghar ta' L-Iburdan*

Ghar ta' L-Iburdan is listed as a Potential Site of Community Importance (pSCI) due to its presence of bat species. This cave is the most important winter roost for the horseshoe bat, *Rhinolophus hipposideros*, with up to approximately 65 individuals being present. It is an underground natural cave extended by man, located in the limits of Rabat. It is several metres deep in three directions, and which has a two-storey plan. Excavations in the seventies revealed that the cave was inhabited during the Roman and Byzantine periods. Ghar ta' L-Iburdan provides evidence for a humble form of dwelling. A considerable amount of pottery was found in the cave dating back to at least the third Century.

3.3.4. *Rdumijiet ta' Malta: Ras il-Pellegrin sa Ix-Xaqqa*

Ras il-Pellegrin is the headland at Fomm ir-Rih bay leading to ix-Xaqqa close to Fawwara. Cart ruts are present on the headland with sheer cliffs leading to the sea. This area has a series of cliff habitat species with a number of migratory birds. Present are steppe and garrigue communities exposed to high winds.

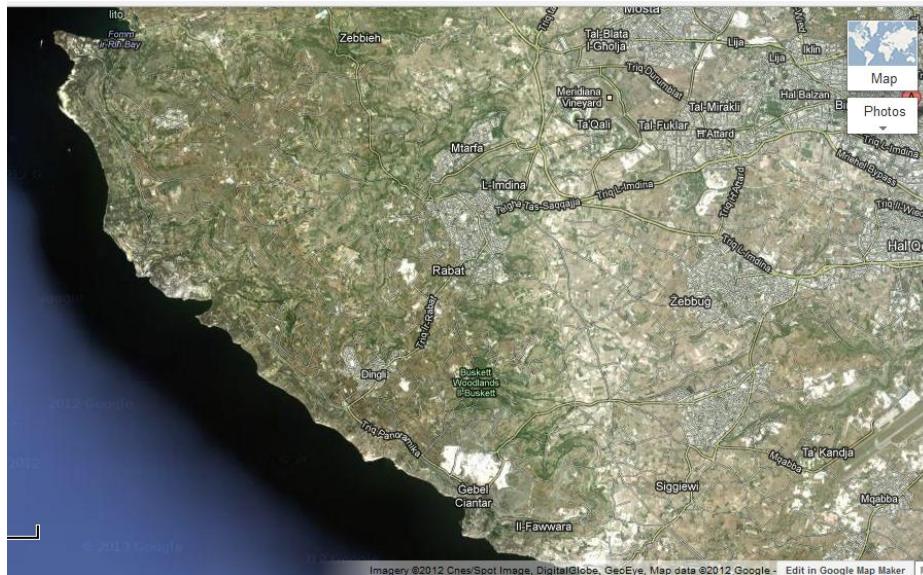


Plate 3.17: Ras il-Pellegrin to Ix-Xaqqa. Source: Google Imagery, 2012.

3.3.5. Buskett- Girgenti

In Buskett's wide, extensive valley system, several habitats, the most familiar being the semi natural woodland characterised by Aleppo pine and Carob trees, are present (refer to plate 3.18) (Malta Environment & Planning Authority (MEPA), 2012). This site is of importance for many woodland and wood related species. A number of insects, particularly those stenoecious species typical of woodland biotypes, are only found in this area of the Maltese Islands. Buskett also serves as a roosting ground for many migratory raptor species such as harriers, falcons and buzzards (Malta Environment & Planning Authority (MEPA), 2012).

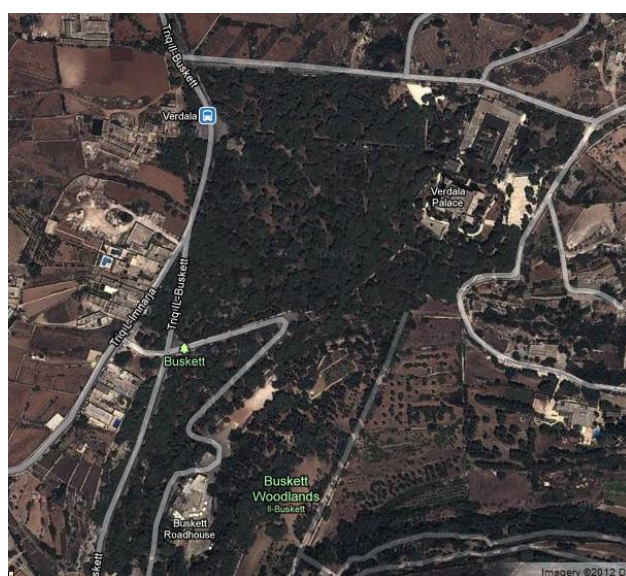


Plate 3.18: Buskett. Source: Google Imagery, 2012.

3.3.6. *Rdumijiet ta' Malta: Ix-Xaqqa sa Wied Moqbol*

Ix-Xaqqa are those cliff faces close to Fawwara resulting in the rocky valley of Wied Moqbol, the largest population of the very rare wild pear in Malta amongst several other tree species are present (refer to plate 3.19)(MEPA, 2012). The very rare, threatened tree species, azarole- *Crataegus azarolus* (ghanzlor) is habituated here. The coastal part of the valley side is also home to the national plant. This area has been protected as a nature reserve with ecological importance since 1996. Malta Environment and Planning Authority has also declared the Wied Moqbol as a Tree Protected Area.

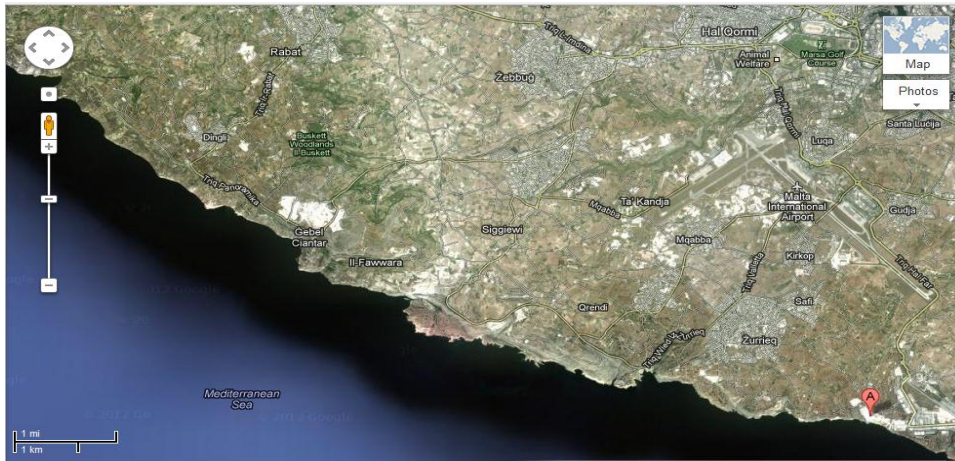


Plate 3.19: Ix-Xaqqa to Wied Moqbol. Source: Google Imagery, 2012.

3.3.7 Il-Maqluba (Qrendi)

Il-Maqluba, meaning upside down, is a doline resulting from a natural depression formed by the collapse of the underlying limestone strata (refer to plate 3.20). It now helps us maintain our underground water supplies as its role as a sinkhole collects rainwater from a three-mile radius. Il-Maqluba is the only natural sub-circular depression that is not filled with sediment. The doline has an area of approximately 6,000m² and it serves as a natural soak-away reservoir with a depth of approximately 15 metres. This area not only supports a dense maquis community but it is also known to be the breeding ground for Malta's National bird, the Blue Rock Thrush- *Monticola solitarius* (Schembri, 1997).

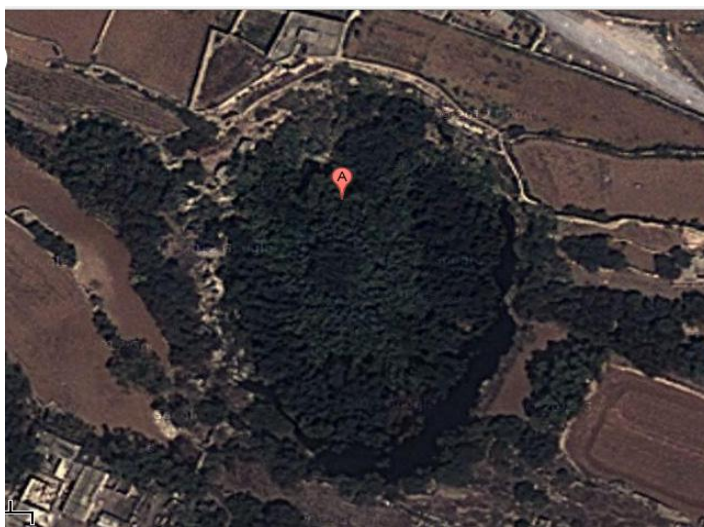


Plate 3.20: Il-Maqluba. Source: Google Imagery, 2012.

3.4. Sites of Community Importance in the East

Globigerina limestone is gently rolling into a flatter landscape in the central and eastern regions.

3.4.1. *Ghar Dalam*

Located at Birzebbuga, Ghar Dalam is an underground cave with evidence of the earliest human settlement, some 7,400 years ago. This cave is one of the only two localities that is home to the woodlouse *Armadillidium ghardalamensis*. This species is endemic to Malta with a small population at risk. The woodlouse is of importance as it is a cave-dwelling species living in the darkest parts of the cave where access is impossible and not allowed. Fossil remains of dwarf elephants, hippopotami, large flightless birds and micro- mammals are all evident in the lower most layers that are more than 500,000 years old (Heritage Malta, 2008). Evidence of the first humans on the island is held in the top layer dating to less than 10,000 years (*ibid*).

3.4.2. *Il-Ballut (Marsaxlokk)*

This saltmarsh is one of the few remaining in the Maltese Islands with animals in various stages of life hidden within the tangle of salt marsh plants (refer to plate 3.21). The surrounding landscape of il-Ballut is dominated by terraced agricultural land with the saltmarsh representing one of the best salt meadows in the Mediterranean (MEPA, 2012). Specific flora and fauna that can withstand harsh environmental conditions such as a rise in salinity during the dry season are present here. Consequently these species are extremely rare requiring protection. As a result, the habitat has also been afforded protection.



Plate 3.21: Il-Ballut. Source: Google Imagery, 2012.

The site description provides evidence that there is an important link between biodiversity and geomorphology through an interface common to both, being the habitat. The geomorphology shaping each site provides a habitat to the protected species. Such an example is the saltmarsh being home to animals in various stages of life or the cliffs acting as breeding grounds for migratory birds. These examples amongst numerous other geomorphological features present in the N2K sites have proven to be refuge to several species as without these features, the habitats would not exist.

Chapter 4

Methodology

Chapter 4

Methodology

Chapter Outline

The scope of this chapter is primarily to outline the methodological approach taken to investigate the geomorphology of the Natura 2000 sites in which the protected habitats lie in and to see the link between these habitats and the geomorphology. In general terms, this approach will comprise four distinct stages: i) A desk study, ii) Ground-truthing, iii) Digitizing, iv) Analysis of the link between the habitats and geomorphology of the studied sites.

4.1. Natura 2000 sites in Malta

Due to the considerable species richness and diversity present, local authorities through the Malta Environment & Planning Authority proposed a number of sites to be considered as Special Areas of Conservation (SACs), which subsequently took on Natura 2000 designation. Those chosen on the main island of Malta are concentrated on the south-western coast up to the northern coast with just Pembroke on the eastern coast (refer to figure 4.1). The pattern of designation on Gozo is different with 9 sites selected on the sister island, while the whole of Comino and Filfla are entirely protected via N2K designation. The Natura 2000 concept and the implications of such designation were examined in the context of the Maltese Islands. Each of the 33 sites designated through this network are protected as a result of the existing diversity harboured within them and as a consequence to species' significant importance. N2K applies to Birds Sites and Habitats Sites also including the marine environment which are divided into biogeographical regions (European Commission, 2012). It is comprised of Special Areas of Conservation (SAC) designated by Member States under the Habitats Directive, and also incorporates Special Protection Areas (SPAs) which they designate under the 1979 Birds Directive (*ibid*). Malta has submitted to the EC a number of sites to form part of this important network. These are 28 **Sites of Community Importance** (eventually Special Areas of Conservation) declared under the EC Habitats Directive and 13

Special Protection Areas declared under the EC Birds Directive (MEPA 2012). The main reasons for the conservation of biological diversity within the 33 sites are various and include, for example, the presence of rdum formations, vegetated sea cliffs, Mediterranean salt meadows, Mediterranean scrubs, Mediterranean salt steppes, Embryonic shifting dunes, Arborescent matorral, thermo-Mediterranean and pre-desert scrub, clifftop phrygas, sub-endemic phrygas, calcareous rock slopes, riparian galleries and thickets, Oleo- Ceratonion assemblages or *Quercus ilex* forest remnants (adapted from table 4.1 below). These are all priority habitats and designated as such through the Habitats Directive.

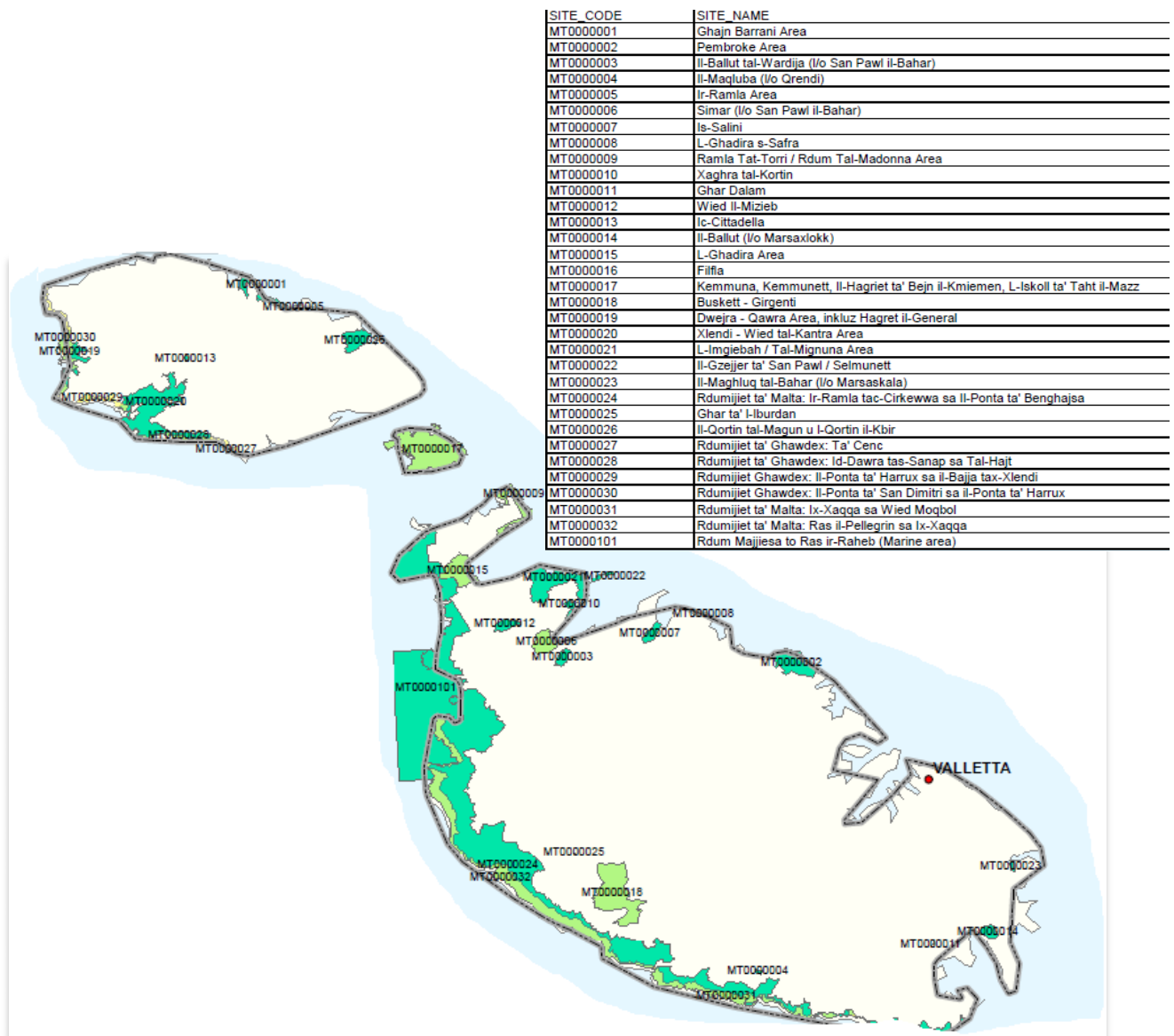


Figure 4.1: The Natura 2000 sites in the Maltese Islands. Source: Natura 2000

Biodiversity type	Species present
Rdum	
Reefs	
Annual vegetation of drift lines	
Vegetated sea cliffs of the Mediterranean coasts	<i>Endemic</i> <i>Limonium spp</i>
Mediterranean salt meadows	
Mediterranean and thermo-Atlantic halophilous scrubs	
Mediterranean salt steppes	
Embryonic shifting dunes	
Aborescent matorral	<i>Laurus nobilis</i>
Thermo-Mediterranean and pre-desert scrub	
West Mediterranean clifftop	Phrygana
Endemic phryganas of the Euphorbio-Verbascion	
Calcareous rock slopes	Chasmophytic vegetation
<i>Salix alba</i> and <i>Populus alba</i> galleries	
Southern riparian galleries and thickets	
Olea and Ceratonia forests	
<i>Quercus ilex</i>	

Table 4.1: The biodiversity being protected in Malta. Source: Composed by Author

4.2. Maps

All maps of the Maltese Islands were printed to the appropriate size with being able to add as much detail as possible. Some maps were adequate on an A4 paper whereas others needed to be enlarged onto an A3 as the area under study had several geomorphological features to plot. These maps highlight all the protected habitats and species present in each site. A legend was composed by the author for mapping all geomorphological features occurring on site. It was more efficient by keeping the same symbols for each feature on every map while ground-truthing on site. The symbols used were composed by the author as those used in past research varied and became too complex for the 1:25000 scaled maps. The features noted to occur within these sites include a sandy beach, saline marsh, sand dunes, graben and horst, terraces, valley system, freshwater wetland, doline, escarpment, phreatic tube, coastal wetland, low rock coastline, karstic terrain, rocky hillside, boulder scree and field, underground cave, sea caves and karstic caves, rock pools, clay talus,

globigerina shore platform, colluvial deposit, sheer sea cliffs, plateaux, butte, quaternary deposit and rdum. Certain geomorphological features in specific sites were labelled with wording as the field plotting got more complex and overcrowding of symbols was avoided as some areas were denser than others in terms of geomorphology.

4.3. Desk Study

Before ground-truthing, a desk study of each site helped to identify certain details. Once all features were identified by first using remote-sensed imagery, several factors were taken into consideration. Important elements for each site such as biodiversity conservation and which habitats and species are being protected by Natura 2000 were identified. The next step was indentifying the geomorphological features of importance on each site. These may have a direct impact on the habitats and species being protected. Therefore the final consideration was to combine the importance of biodiversity conservation, identified by the initial Natura 2000 surveys which MEPA had commissioned, with the geomorphology present on site.

4.4. Ground-Truthing

Remotely sensed satellite imagery did not provide adequately fine resolution to enable mapping of individual sites in Malta therefore all sites had to be visited with some areas being inaccessible. Thus, further research had to be made and in the case of the caves, a specialised member of MEPA helped to identify each one through his past work on these features. The first sites visited, during field surveys, were Dingli Cliffs and Fomm ir-Rih. Over here, a wide span of land can be observed from vantage points, where most geomorphological features can be seen and mapped. Photocopies of the original maps of a scale of 1: 2500 cm were taken on each site and mapping progressed. The first site where mapping began was the coastal area between Rdum Majjiesa” and “Ras is-Raheb”. This area boasts of numerous geomorphological features, ranging from boulder scree and boulder field formations (Block- scree formation) to clay taluses, escarpment, hanging valleys, plateaux and sandy and pebble beaches. For some sites, deemed less complex from the landform point of view, remote-sensed imagery (notably Google Earth) was utilized. In fact, Google Earth was used prior to each field survey trip, with a view to examine each

site beforehand and familiarize oneself with features present. By zooming in at an ideal scale, landform features were clear enough to be mapped in draft form. In the case of uncertainties, further research and ground-truthing, was conducted to clarify. Subsequent to field surveys, the maps were re-plotted on a new ‘clean’ map and scanned for eventual digitization.

4.5. Digitization

Once the ground-truthing process was accomplished, all geomorphological features were transferred onto the “clean”, photocopied maps and eventually presented onto the original ones. The hard copies of maps were transferred into a digital medium by using Geographic Information System (GIS). This was used to digitize the cartography before analysing the geographical data. Besides being aesthetically beneficial, this will aid the analysis as some layers were removed off the base map making them visually clearer. The MEPA base maps were used to show the Natura 2000 layers exposing the protected species on each site. However, new maps were created by replacing this layer with the digitized geomorphology of each area. The two separate maps were used as a comparison between the geomorphology and the species under Natura 2000 found within it. A consistent legend on each map was used showing the geomorphological features and each one was given a title: a) Geomorphology b) Natura 2000 site.

4.6. Analysis

Once the maps were digitized, maps a) and b) of each site were used to progress with the aim of the study. The analysis started off with a general description of the geomorphological features defined shaping the landscape in each site. Each feature was linked to biodiversity adaptabilities. This was followed by a brief overview on the geomorphological features shaping each individual Natura 2000 site in which the habitats are found. A detailed analysis described the possible changes in geomorphology due to either natural processes or anthropogenic interference which will directly or indirectly also affect the habitats that lie within this landscape in

either a negative or positive way. The vulnerability of changes in geomorphology is reflected on the biodiversity present in these areas, thus threatening their habitats. Therefore, once these geomorphological features are further advanced or completely demolished, then those habitats are at risk. However, the geomorphology is also reflected in a positive way on the habitats in that area either through shelter or essential needs.

4.7. Limitations of the Study

Natura 2000 has 10 sites in Gozo and 1 site in Comino which unfortunately could not be included in the study. This is due to time constraints of a period just over 3 months to conduct the whole project. Therefore only the 22 Natura 2000 sites in Malta were mapped and used in the analysis study. Another limitation was the use of satellite imagery in which adequately fine resolution is not providing thus this method was not suitable for Malta. Maps a) of the Natura 2000 SPAs mapped by MEPA had minor errors on the vegetation cover; however these maps were still used due to time constraints.

Chapter 5

Results &

Analysis

Chapter 5

Results & Analysis

5.0. Introduction

This chapter presents the results of the geomorphology for each of the investigated sites. The sites are specifically shown on 21 maps (listed below) of which some are overlapping geographically. All Natura 2000 site names have been individually mapped with the exception of the following due to geographical overlap: 1) ir-Ramla ta' Cirkewwa to il-Ponta ta' Benghajsja and 2) ix-Xaqqa to Wied Moqbol. These have been spread out onto three maps labelled as a)Malta Coastal Cliffs part 1 b)Malta coastal cliffs part 2 c)Rdumijiet ta'Malta: Wied Moqbol to Ponta ta'Benghisa. A description on each geomorphological feature identified is given with the link to biodiversity adapting on each specific area. The landscape of each Natura 2000 site is in-part described by giving an overview of the geomorphology that shapes the area. In the analysis, the vulnerability of changes in geomorphology is reflected on the biodiversity present in these areas, which threatens their habitats.

5.1. Geomorphology

5.1.1 Introduction

Distinctive geomorphologic features and anthropogenic interferences have shaped the Maltese Islands in the way it is today. Although Malta is comprised of a set of similar characteristics which shape the whole island, each site is unique with different geomorphological features that make up the landscape. Each feature may provide a habitat to one of several species which are being afforded protection under Natura 2000. Therefore a change in these features may have a profound negative influence on the biodiversity. The present study has identified some 26 distinct geomorphological features within the selected area of study on the island of Malta in which the Natura 2000 sites are situated (Refer to table 5.1). Many of these features are interlinked and overlapping- one feature eventually changing into another, as a

result of geomorphological change due to numerous factors responsible for the ‘evolution’ of landform.

Site Name	Geomorphological Features
Ramla tat-Torri/ Rdum tal-Madonna Area	Karstic terrain, Sandy beach, Sand dunes, Low lying rocky coastline, Doline feature (? Littoral sinkhole), Sheer sea cliffs, Block scree, Sea cave
L-Ghadira Area	Graben, Sandy beach, Sand dune, Saline marsh, Karstic terrain,
Wied il-Mizieb	Horst, Hanging valley, Karstic terrain
L-Imgiebah/ Tal-Mignuna Area	Karstic terrain, Block scree, Boulder field, Sandy beach, Valley system, Clay talus, Globigerina shore platform, Colluvial deposit, Sheer sea cliffs, Sea cave, Fault
Il-Gzejjer ta’ San Pawl/ Selmunett	Globigerina shore platform, Block scree, Sheer sea cliffs, Karstic terrain, Low lying rocky coastline, Superficial sea cave, Natural tunnel, Collapsed sea cave
Xaghra tal-Kortin	Hanging valley, Rocky hillside, Cliffs, Block scree, Boulder field, Sea cave
Simar (San Pawl il-Bahar)	Graben, Valley system, Freshwater wetland
Il-Ballut tal-Wardiya (San Pawl il-Bahar)	Karstic terrain
Is-Salini	Low lying rocky coastline, Saline marsh, Valley system
L-Ghadira s-Safra	Transitional coastal wetland
Pembroke Area	Karstic terrain, Low lying rocky coastline, Rock pools
Rdum Majjiesa to Ras is-Raheb (Marine Area)	Plateau, Block scree, Boulder scree, Boulder field, Cliffs, Clay talus, Sandy beach, Karstic terrain, Butte, Globigerina shore platform, Sheer sea cliffs, Valley system, Sea cave
Malta Coastal Cliffs part 1	Cliffs, Block scree, Sheer sea cliffs, Low lying rock coastline, Karstic terrain, Clay talus, Sea cave, Arch, Doline, Fault
Malta Coastal Cliffs part 2	Sea cave, Cliffs, Block scree, Sheer sea cliffs,

	Karstic terrain, Valley system
Ghar ta' L-Iburdan	Underground cave
Rdumijiet ta' Malta: Ras il-Pellegrin sa Ix-Xaqqa	Clay talus, Cliffs, Block scree, Boulder field, Sandy beach, Globigerina shore platform, Karstic terrain, Cliff cave, Sea cave
Buskett- Girgenti	Valley system, Escarpment, Karstic cave
Rdumijiet ta' Malta: Wied Moqbol sal-Ponta ta' Bnghisa	Karstic terrain, Deep gorge, Cliffs, Block scree, Boulder field, Artificial scree, Sheer sea cliffs, Quaternary deposit, Sea cave, Karstic cave, Valley system
Il-Maqluba (Qrendi)	Doline (Karstic depression), Escarpment (Sheer cliff face)
Ghar Dalam	Phreatic tube, Valley system
Il-Ballut (Marsaxlokk)	Sandy beach, Sand dunes, Saline marsh

Table 5.1: The 26 geomorphological features identified, which in-part shape 22 Natura 2000 sites in Malta.

5.1.2. Description of geomorphological features and their relation to biodiversity

- *Horst*

Horst is an upstanding fault block of the earth's crust by tectonic processes bounded by normal faults or graben (Goudie, 2000). A system of horst and graben structures of east-northeast trend gives rise to a series of rifts and valleys north of the Great Fault (MEPA, 2012). However in the south of the Great fault there are no well-defined horst and graben systems (Schembri, 1997).

- *Graben*

Graben is a depressed block forming a valley or plain which is produced by faulting and subsidence or uplift of adjacent blocks bordered by parallel faults (Goudie, 2000). These are usually side by side with horsts. Single or multiple graben can form a rift valley (Pedley, House, & Waugh, 1976).

- *Plateau*

Plateau is also known as a tableland as it is an elevated area of relatively flat terrain which is frequently separated from adjacent areas by steep slopes (Goudie, 2000). Plateaux in Malta have been formed by erosion of water and possibly cut by rivers and broken by deep narrow valleys. The plateaux found in Malta consist of bare rock and stony platforms with little available water and are usually characterised with a steppe or garrigue community in different stages of ecological succession (MEPA, 2012).

- *Butte*

A butte, on the other hand, is a small, flat-topped, isolated hill with steep, often vertical sides standing isolated on a flat plain (Goudie, 2000). This is an attribute to the erosion of an older land surface.

- *Low lying rocky coastline*

Solid bed-rocks predominate this type of coastline which mainly characterizes the northern part of Malta (Schembri, 2003). These are biologically rich environments as a large number of factors such as the effect of tides and high availability of light favour life on rocky shores. However, those species in the Maltese Islands found in these environments are vulnerable to high salinity conditions, wave exposure, temperature, desiccation and general stress (MEPA, 2012).

- *Karstic terrain*

This limestone topography is typified by the dominant erosional process of solution in which the landscape is largely shaped by the dissolving action of water on carbonate bedrock creating a network of passages (Schembri, 1997). When carbon dioxide is dissolved into water, carbonic acid is produced which when in contact with the calcium carbonate in limestone reacts with the rock to form calcium bicarbonate. This is soluble and is carried away in solution which gradually weathers the limestone. This results in unusual and distinct scenery consisting of caves, springs, and dolines (Goudie, 2000). As a result of the process of dissolution, caves, sinkholes, springs, and sinking streams typical of a karst landscape develop. Alkaline

soils characterise karstic environments and create conditions where water availability differs according to the surrounding terrain. As a result, there is a definite line of distinction between the karst and the surrounding environment brought about by a dramatic change in vegetation (NSW Government, 2011).

- *Doline feature*

This conical depression is common in Malta as it is a limestone feature which is formed by the solution and/or collapse of underlying limestone strata as a result of karst processes (Goudie, 2000). The surface features and subterranean drainage network of a karstland are developed to form a karst topography including surface features such as a doline through the processes of limestone solution (Field, 2002). These may form gradually or suddenly by natural processes of erosion or gradual removal of soluble bedrock by percolating water, collapse of a cave, or lowering of the water table.

- *Escarpment*

An escarpment separates two relatively level areas of differing elevations. It is a steep slope formed as a result of erosion or faulting however in Malta it is usually a result of a slump due to the softer underlying Blue Clay. It usually defines one series of sedimentary rocks to another series of different age and composition and in the case of Malta it is largely comprised of Upper Coralline limestone.

- *Sheer sea cliffs*

The steep slopes are probably of tectonic origin, formed from Lower and Upper Coralline limestone through abrasion of marine waves. They border most of the island's coast characterizing the western coastline. Due to the lack of mass movement processes, sheer sea cliffs lack shore platforms at their feet (Magri, 2002). The sea cliffs are colonised by rupestral plant communities' also providing an ideal nesting habitat for many species of sea birds (MEPA, 2012), not only on the various ledges but also within the rock fissures on the vertical face. These geomorphological features display a complex pattern as a result of long continued changes in sea level, climate and the balance between sub-aerial and marine processes (Goudie, 2000). These factors result in an unstable environment with a high erosion rate forming

wave-cut notches, caves and arches. Therefore only as a wave subsides and impact on the cliffs lessens will vegetation cover the sea cliffs.

- *Globigerina shore platform*

These features are common in the Maltese coastline where sea cliffs are exposed to wave action. Several shore platforms outcropped by globigerina are exposed on parts of the Maltese coastline. These narrow flat areas of land are usually found at the base of sea cliffs formed by a combination of processes, including wave action, subaerial weathering and biogenic activity. The formation depends on the nature of the rocks and their structures, the nature of the main processes operative upon them, their age and history and on tidal characteristics (Goudie, 2000).

- *Notches*

This landform is also a characteristic in the Maltese, limestone coast, often developing at the base of a cliff, platform or reef flat (Goudie, 2000). As destructive waves hit the cliff face, undercutting creates a wave-cut notch as a result of corrosion and hydraulic power. This eventually can enlarge into a cave.

- *Sea cave*

The formation of caves may involve a combination of erosion of water, tectonic forces, micro-organisms, pressure and atmospheric influences. However, these features may also have formed during low stands through karstic processes. Littoral caves are formed by wave action in the zones of weakness in sea cliffs. Caves develop along lines of weakness and thus their pattern depends on the regional jointing, folding and faulting (NSW Government, 2011). In Malta, cliff caves are inhabited by a wide variety of insects, bats, flora and a number of these are endangered species due to their isolation, however with no crypto-fauna present in Malta (MEPA, 2012).

- *Karstic cave*

Already existing caves are opened through coastal erosion as water starts to widen the cave forming a karst cave. Many of these karst caves found on the coast of Malta have an opening to the sea which is widened by the waves (MEPA, 2012). Underground caves are commonly formed in limestone by solutional processes of

joint enlargement. In solutional caves, canyons in the more circular phreatic cave tubes are cut by normal stream or vadose conditions as a result of the lowering of the water table (Goudie, 2000). Over geological epochs, cracks expand to become caves.

- *Phreatic tube*

This formation is a result of rock saturated in water below the water table (Goudie, 2000). A cave-like feature is created through limestone solution and usually by a combination of phreatic followed by vadose action. Such formations can also result from erosion by underground river systems.

- *Rdum*

This landform consists of a rocky area, with sheer cliffs and crumbling limestone formations. These sites are usually important for their garrigue and steppis vegetation, as well as a suite for faunal species including reptiles such as the chameleons and skinks as well as many species of invertebrates (MEPA, 2012). Many of the rdum landforms are also important for birds, including sea birds such as shearwaters among others. The presence of boulder scree (terrestrial) and boulder field (marine), which form part of this landscape, inherent geomorphological instability (Schembri, 2003). These landscapes are vulnerable due to the underlying soft rock, influenced by aeolian and water processes and wave action.

- *Clay talus*

Blue Clay in Malta overlies the Globigerina Limestone formation. When wet it erodes very easily and forms clay taluses which flow out over the underlying rock (Schembri, 2003). Under this impermeable layer of rock lies the perched aquifer thus encouraging vegetation growth. However, clay taluses are unstable under the influence of aeolian and water processes.

- *Valley system*

V-shaped valleys characterise the Maltese islands acting as a watercourse during the rainy season leaving them dry during dry periods (Anderson & Schembri, 1997). These formations are a result of vertical erosion (in the form of abrasion, hydraulic action and solution) in the previous river channel. The distinctive v-shape is created by gradual mass movement of materials occurring down the valley sides. Another

characteristic are the hanging valleys in which the floor of the tributary channel is at a higher relief than the main channel into which it flows. Due to valleys' rare habitats in a semi-arid country such as Malta, such watercourses are considered highly valuable ecosystems. Moreover they often harbour rare and endemic species; with the endemic freshwater crab being a good example (MEPA, 2012). However, this highly depends on climatic conditions being vulnerable to flooding or drought.

- *Deep gorge*

With a deeper and narrower section of a river valley and usually with vertical narrow rock walls is the formation of a gorge. This is a result of softer, soluble limestone rock forming caves systems in the rock which then collapse resulting in a gorge. In Malta a gorge may have also developed as a result of water erosion during the pluvial period.

- *Sandy beach*

These are a result of coastal accumulation of varied types of rocks and sediments of different shapes and sizes. In Malta, the sediment is a breakdown of the rock and is transported through waves forming the familiar pocket beaches scattered around the island. The beach profile depends on the size of the sediments and the steepness of the waves therefore these profiles may be highly changeable (Short & Wright, 2006). Sandy beaches are dynamic features which change seasonally depending on wave energy with a high energy decreasing the beach profile (Goudie, 2000). Sea level fluctuations also affect the beach profile. Thus, a beach is an unstable environment affecting those animals feeding off the deposited materials. Insects, crabs and birds feed on these burrowing animals, all being exposed to changes and harsh conditions.

- *Sand dunes*

Sand dunes are an accumulation of sediment which in Malta is formed by constructive waves allowing the accumulation of sand and through aeolian processes the sand is blown inland (Cassar & Stevens, 2002). The Maltese sand dunes consist of quartz sand and can also consist of carbonate sediments (MEPA, 2012). Dunes

may be stabilized, fixed and/ or degraded depends on the total package of environmental factors favouring aeolian processes (Goudie, 2000). Once the dune is formed there is ecological succession in which nutrients are added by storm waves allowing pioneer species to colonize the dune (Cassar & Stevens, 2002). The general structural and functional 'health' of a dune system is indicated by the habitat type which is thus of exceptional importance (JNCC, 2012). The deep roots keep the dunes together however they are still vulnerable and exposed to changes. Coastal dunes provide critical habitat for plants and animals and in some cases serve as important sources of fresh water. Therefore these need important protection against coastal erosion and flooding (Goudie, 2000).

- *Saline marsh*

With only few characterising the Maltese islands' low-lying coasts, saline marshlands are mud-flats in the high intertidal zone between land and salt water (MEPA, 2012). They trap sediment and build up the marsh surface whilst supporting dense stands of halophytic plants thus having both ecological and geomorphological importance (Goudie, 2000). Besides playing a role in the aquatic food web, salt marshes support terrestrial animals and provide coastal protection.

- *Transitional coastal wetland*

The terms transitional refers that coastal wetland which is between a freshwater wetland and a saline marshland. This is a result of rainwater collecting in a depression next to the sea which often become colonised by species typical of freshwater to some extent of tolerance to saline conditions (MEPA, 2012). Transitional coastal wetlands are seasonal as during the dry period, the only water arriving in these depressions is seawater (Malta Virtual Field Sites). Therefore this habitat supports species at different periods of the annual cycle. However, the specific biota which characterises such a wetland may consist of some long-lived and tolerant brackish water species throughout the freshwater phase (*ibid*).

- *Rock pools*

Rock pools are in the intertidal zone therefore they fill with seawater during high tide but are left as a visible separate pool at low tide. Species found here are hardy

organisms such as sea stars, mussels and clams as they have to cope with a constantly changing environment.

- *Freshwater wetland*

This area in Malta is usually seasonally saturated with water due to high temperatures during the dry period (MEPA, 2012). Wetlands are considered one of the most biologically diverse of all ecosystems (Goudie, 2000). Being close to the coast these environments are strongly influenced by saline conditions.

- *Colluvial deposit*

This material is derived from the erosion of weathered bedrock which through wash and mass movement processes is transported and deposited on slopes (Goudie, 2000). These soils are typically high in clay with a moist and wet texture during the rainy season.

- *Terraces*

Although terraces are man-made, they have been listed in the ground-truthing as they cover a vast area of the Natura 2000 sites. This practise is common in Malta due to its topographic and geomorphological conditions. These structures are suitable for cultivation on slopes with difficult soil conditions (Role).

5.2. Geomorphology mapped shaping the Natura 2000 habitats

The following analysis highlights each Natura 2000 site with its protected species mapped by MEPA in relation to the geomorphology mapped in this study. However, some slight errors of the primary data need to be taken into consideration as only the geomorphology was mapped for each site whilst using the flora and fauna from previous data. Such an example is the **Olea-Ceratonion** which is merely a label and that forests, in the true sense of the word, do not exist per se except at Buskett, where woodland habitat still occurs.

5.2.1. *Ramla tat-Torri/ Rdum tal-Madonna Area (refer to map 1a and 1b)*

The pocket beach, Little Armier bay, characterises a part of this coastal area being sheltered by a headland protecting the beach from erosion and supplying it with sediment through long-shore drift. The total length of the beach is roughly 256 metres with a width of 33 metres extending backshore. Sand dunes characterise the back of the beach at a further depth of 30 metres backshore followed by an artificial built-up area. The fixed beach dunes are vegetated with **Crucianellion maritimae** and the dunes characterized by *Panocratium maritimum* and *Euphorbia terracina*. A low-lying rocky coastline dominates the coastline neighbouring the sandy beach shadowed by an extensive area of karstic terrain. A doline feature (? littoral sinkhole), known as Id-Drangunara, has formed on the karstic terrain which is visible from a distance, thus acting as a landmark to the area. The entire karstic terrain is habitat to extensive areas of vegetation cover consisting of Thermo-Mediterranean and pre-desert scrub. There is a sudden change in coastline to sheer sea cliffs characterised by West Mediterranean cliff-top phrygana. The sea cave, Ghar ic-Comb has developed over the years in these cliffs. Rdum characterise the rest of the coastline with boulder scree vegetated with endemic *Limonium* and chasmophytic vegetation, however karstic terrain still lies behind this area. L-Ghar ta' Zamzam is also a sea cave which however habitats the rdum in this site.

5.2.2. *L-Ghadira Area (refer to map 2a and 2b)*

The predominant geomorphological feature in this Natura 2000 site is the saline marsh which occupies a large area on the visible graben. This marsh is vegetated by Mediterranean salt meadows and Mediterranean and thermo-Atlantic halophilous scrubs. A sandy beach of approximately 1km long extends throughout the entire coastline of Ghadira. Sand dunes have also developed behind the sandy beach, close to the saline marsh on which one finds various stenocious species such as *Euphorbia terracina*, *Lotus cytizoides* among others. An extensive area of land, immediately beyond the low-lying marsh regions, is characterised by the typical karstic terrain covered by Thermo-Mediterranean and pre-desert scrub and West Mediterranean cliff-top phrygana with an area also vegetated by pseudo-steppe consisting of grasses and annuals of the *Thero-Brachypodietea*.

5.2.3. Wied il-Mizieb (refer to map 3a and 3b)

This Natura 2000 site is situated on a horst block predominant with karstic terrain which hosts much of the Thermo-Mediterranean and pre-desert scrub, Mediterranean clifftop phryganas with pockets of the **Olea-Ceratonion** forests. One area of karstic terrain also provides a habitat for *Tetraclinis articulata* 'forests'. Two hanging valleys fall along the horst system through the karstic terrain characterising this site as Wied Mizieb.

5.2.4. L-Imgiebah/Tal-Mignuna Area (refer to map 4a and 4b)

This site covers a complex network of geomorphology designed by diverse features shaping the landscape. **Olea-Ceratonion** forests characterise a few areas away from the coast with one part vegetated by *Quercus ilex* and *Quercus rotundifolia* forests. However, *Quercus ilex* is only found here even if the biotope is called so. Terraces shadow the entire coastline covering an extensive area showing the hilliness in the land with pockets of Southern riparian galleries and thickets. Karstic terrain comprises the other half of the land filling in pockets between the terraces and the coastline. This environment is colonised by Mediterranean salt steppes and Thermo-Mediterranean and pre-desert scrub. Rdum characterise a large extent of the coastline together with boulder scree and occasional boulder field vegetated with chasmophytic vegetation. The valley system of Wied L-Imgiebah extends throughout the terraced land adjoining the coast with the formation of a sandy beach pocketed between the rdum landscapes. In some area, the rdum is fragmented by clay talus. However as a fault cuts through the landscape, it is neighboured with clay talus extending over 200 metres. There is a sudden change in geomorphology when a globigerina shore platform segments a part of the coast. Another fault dissects sheer sea cliffs, Rdum il-Bies, which characterise one fifth of the coastline colonised by endemic *Limonium* spp. Ghar ta' Rdum il-Bies took its sea cave formation in these sea cliffs. Other small sea caves also shape a part of the rdum. This site has also gained importance for its colluvial deposits on the coast.

5.2.5. *Il-Gzejjer ta' San Pawl (refer to map 5a and 5b)*

Karstic terrain outcrops the entire surface of the St. Paul's Islands vegetated with endemic *Limonium* spp. As sea cliffs characterise roughly 70% of the islands' coastline, the remaining has an rdum landscape in just two distinct areas. Boulder scree falls gently on these areas with one main boulder field present on the larger island. One part of the main island experiences a lower coastline characterised by a globigerina shore platform. With a similar height above sea level coastline, the islands are attached by a low lying rock coastline with an average of just 1metre above sea level. A series of superficial sea caves extends along the southern coast of the larger island. A natural tunnel has developed on the opposite side of the island with "L-Ghar tal-Gzejjer" being a collapsed sea cave on the smaller island.

5.2.6. *Xaghra tal-Kortin (refer to map 6a and 6b)*

A hanging valley falls down ending in the sea with terraced land on its side shadowed by a rocky hillside. The rest of the entire coastline has an rdum landscape consisting of boulder scree with boulder field throughout the coastline, however more concentrated in one area. This environment is colonised by Thermo-Mediterranean and pre-desert scrub and chasmophytic vegetation with West Mediterranean clifftop phrygas and **Olea-Ceratonion** forests covering an extensive area of the rdum. One sea cave shapes the rdum on the far end of this Natura 2000 site, known as il-Fekruna.

5.2.7. *Is-Simar (refer to map 7a and 7b)*

Is-Simar sitting on a graben block is surrounded by a valley system with terraced land. A freshwater wetland is situated about 100 metres behind the sandy beach which has developed at the mouth of the valley.

5.2.8. *Il-Ballut tal-Wardija (refer to map 8a and 8b)*

This site is far for geomorphologically complex, as it's only characterised by karstic terrain which supports an extensive area of *Quercus ilex* and *Quercus rotundifolia* forests and a smaller area is vegetated by Mediterranean pine forests with endemic *Mesogean* pines.

5.2.9. *Is-Salini (refer to map 9a and 9b)*

The saline marshland is around 750 metres in depth with a width just less than 200 metres. This large area is continuously being supplied not only by seawater but its distribution is at the mouth of a hanging valley. The mud and sand environment is colonized by Mediterranean salt meadows, Mediterranean and thermo-Atlantic halophilous scrubs and Southern riparian galleries and thickets. The saline marsh is buffered by a low rocky coastline separated this feature from the sea.

5.2.10. *L-Ghadira s-Safra (refer to map 10a and 10b)*

L-Ghadira s-Safra hosts temporary ponds with Mediterranean and thermo-Atlantic halophilous scrubs. Thus, its main geomorphological feature being the transitional coastal wetland is of significant importance.

5.2.11. *Pembroke (refer to map 11a and 11b)*

Pembroke is characterised by a low-lying rocky coastline vegetated with endemic *Limonium* spp. Karstic terrain in which rock pools have developed, dominates the entire site colonised by Mediterranean salt meadows and grasses and annuals of the *Thero-Brachypodieta* with a few areas of anthropogenic interference. Few karstic areas are also covered with West Mediterranean clifftop phrygas and *Sarcopoterium spinosum* phrygas.

5.2.12. *Rdum Majjiesa to Ras ir-Raheb (refer to map 12a and 12b)*

With numerous geomorphological features, this site represents a complex coastal landscape. This site consists of visible layers of exposed rock with three headlands and their pocketed sandy beaches. Sheer sea cliffs shape the coastline near Fomm ir-Rih with one distinct sea cave formation; L-Ghar tat-Trozza and a neighbouring valley system flowing down to the cliffs. There are a total of 4 pocket beaches mainly of sandy material sheltered between headlands. These beaches are sheltered and receive material through longshore drift from the surrounding eroded rock. All headlands are characterised by rdum outlined with boulder scree and boulder field with another sea cave, Ghar Marija, shaping this landscape formation. Three distinct

plateaux outline each headland separating them from the rest of the landscape with their elevated tabletop with Karraba headland presenting a visible butte. At Gnejna bay a large globigerina shore platform characterises the bay adjacent to the sandy beach. Clay talus gently rolls along the coastline in several areas covering extensive areas of each bay.

5.2.13. Malta coastal cliffs part 1 (refer to map 13a and 13b)

The entire coastline is dominated by coastal cliffs in this site on the geographically southern coast. Three valley systems flow perpendicular to the coast extending down to the sea along the sheer sea cliffs. A total of six sea caves characterises these sea cliffs each hosting an individual habitat; Ghar Raddiem, Ghar Manwel, Ghar Lapsi, L-Ghar tax-Xaqqa and Ghar il-Hwejjjaq leaving one unidentified. Two arches have also formed and taken shape on parts of the coast, one of them known as il-Hlejja. Rdm define lean areas along the coast though karstic terrain dominates the rear part of the coast. Scarce pockets of boulder field characterize the sea adjacent to the boulder scree. The remaining fragment of land is shaped by a low lying rocky coastline, a large coastal doline feature known as il-Maqluba which is a result of collapsed sea caves and an inland sea. Two faults dissect the coast in two different areas result in a sheer drop in the land.

5.2.14. Malta coastal cliffs part 2 (refer to map 14a and 14b)

The entire coastline is characterised by sheer sea cliffs with a total of nine sea caves formed within. Ghar it-Tarag, L-Ghar tad-Dahla and another unidentified cave name are individually shaped into the sea cliffs. The other six sea caves all form part of Blue Grotto: Il-Hnejja, Ghar Raddiena, L-Ghar tal-Munqar, Ghar Qattuas, It-Tieqa and L-Ghar taht Il-Hnejja. Three small distinct patches of land are shaped by rdm with the typical boulder scree formation. Boulder field scatter in the sea extending along the coastline. Two valley systems; Wied Moqbol and Wied il-Bassasa shape the landscape along this coast cutting through the cliffs.

5.2.15. Ghar ta' L-Iburdan (refer to map 15a and 15b)

This Natura 2000 site is an underground cave covering an area of 1,400 square metres with no vegetation of importance being protected by Natura 2000. This irregular layout has three main areas connected by a number of corridors. Ghar ta' L-

Iburdan was probably used for habitation during the Roman period and is a Special Area of Conservation due to its cultural heritage (MEPA, 2012).

5.2.16. Rđumijiet ta'Malta: Ras il-Pellegrin sa ix-Xaqqa (refer to map 16a and 16b)

A total of ten sea caves have been identified, however one unidentified, along this long coastline dominated by sheer sea cliffs. These are the Ghar it-Torkija, L-Ghar tal-Battax, L-Ghar tax-Xaqliebi, Ghar id-Dwieb, Migra consisting of il-Ferha and Ghar Dosow, Il-Mina, L-Ghar tat-Trozz and Ghar Marija. A sandy pocket beach lies between rdum and boulder scree with scattering boulder field. A globigerina shore platform known as il-Blata tal-Melh characterises a part of the coastline.

5.2.17. Buskett (refer to map 17a and 17b)

Characterised by two valley systems of Wied il-Buskett and Wied il-Luq, Buskett is situated in a valley bed surrounded by slopes and dominated by Mediterranean pine forests with patches of *Olea* and *Ceratonia* forests. Other pockets of vegetation spread along the valley bed also consisting of the *Quercus ilex* forest, giving the site its status as a Special Area of Conservation. Karstic terrain shapes a particular area of land with the development of two karstic caves relatively close to one another.

5.2.18. Rđumijiet ta Malta: Wied Moqbol sal-Ponta ta Benghisa (refer to map 18a and 18b)

Five main karstic caves with smaller caves found within, six of which are identified along the sea cliffs. These are Ghar Gamizi, it-Toqbiet, Ghar ir-Rih and Ghar Tentuxa, Ghar Imqabad and Ghar Hasan with one sea cave known as Ghar Kilwa. Two valley systems shape the landscape, Wied il-Mixta and Wied Znumber acting forming a deep gorge with sheer steep sides. The entire topography is characterised by a karstic terrain excluding one area of terraced land. Sheer coastal cliffs are consistent throughout the coastline experiencing some patches of rdum and boulder scree with one area covered by artificial scree.

5.2.19. *Il-Maqluba* (refer to map 19a and 19b)

This Doline feature is a karstic depression with a sheer face having a distinct escarpment. Although it is several metres below the surrounding land, it is highly vegetated by *Laurus nobilis* and *Tetraclinis articulata* 'forests'. making this visibly challenging. The surrounding environment is colonised by calcareous rocky slopes with Chasmophytic vegetation.

5.2.20. *Ghar Dalam* (refer to map 20a and 20b)

Ghar Dalam known as the underground cave is a phreatic tube consisting of six layers with nearly half of the cave not open to the public. A valley system flows right towards the cave showing possible influence on its formation; however this site is an SPA mainly due to its cultural heritage.

5.2.21. *Il-Ballut* (refer to map 21a and 21b)

This site is characterised by a sandy beach colonised by shadowed by a saline marsh in which sand dunes took their formation. The dunes are colonised by Mediterranean salt meadows and Southern riparian galleries and thickets but the marsh is mainly dominated by *Salicornia* and Mediterranean and thermo-Atlantic halophilous scrub.

5.3. Geomorphology as a Habitat to Biodiversity

In order to conserve the biodiversity, the geomorphology in which these habitats are found should also be considered as many of these are dynamic features as well as suppliers and shelters for species. The geomorphology of the Maltese Islands is constantly changing due to factors such as wave action, wind, biological and chemical processes as well as anthropogenic interference re-shaping the landscape. Therefore, once these geomorphological features are further advanced or completely demolished, then those habitats are at risk. Natura 2000 fails to consider the importance of landform within each site and the benefit these features might have, primarily in providing a habitat or even the disadvantages the dynamic geomorphology might cause. However, the geomorphology is also reflected in a positive way on the habitats in that area either through shelter or by providing essential needs. This only proves the further need for geo-conservation.

The steppe and garrigue community often carries connotations of wasteland and a general perception of unproductive land. Therefore these sites occasionally took the form of fly tipping by insensitive individuals, as well as the more serious dumping of construction waste by some building contractors. However the attitude of NGOs and other environmental and educational authorities, this concept has changed. The geomorphology in which these communities are found should also be conserved as it provides habitat to those species composing the environment. Several species found in the steppe community are native to the Maltese Islands which live in the steppe community characterising the karstic terrain, plateaux and sea cliffs.

5.3.1. Positive Impacts on the Geomorphology affecting Biodiversity

Some impacts on geomorphology may affect biodiversity in a positive way advancing growth and stabilising habitats. Rainfall quickly moves through crevices in the rock of a karstic terrain escaping into the ground. Openings in the bedrock increase in size and an underground drainage system begins to develop with more water passing through further accelerating the formation of karst. This eventually results in subsurface caves. As a result of the dissolution and the creation of a complex underground water flow network, the karstified limestone acts as an aquifer where water can be stored and used for irrigation. Thus the geology of the landscape can also identify the species richness. The presence of springs, occasionally found overlying the impervious Blue Clay stratum, requires no pumping and is easily fed to vegetation under gravity along channels. This emphasizes the importance of the geomorphology of the area to supply species with its essential nutrients and other minerals to survive. Therefore managing the karstic environments is vital to the Maltese Islands as it may increase spring and groundwater quality as well as a healthier ecosystem with high quality habitat.

In the case of a wetland flooding is seen as an important factor as it produces such environments. The duration of the flooding determines its vegetation being either aquatic, swamp or marsh. Growth of specially adapted plants is favoured by the prolonged presence of water which also promotes the development of characteristic wetlands soils which are important factors affecting the biota (EPA, 2012). These areas are home to a wide range of flora and fauna thus considered to be the most biologically diverse of all ecosystems. Besides acting as flood control, wetlands in arid regions such as Malta help provide regular water supply and fertile soils. These

systems are also directly linked to groundwater and can regulate the quantity and quality of water below the ground. In a wetland community both sediments and nutrients are cycled thus balancing terrestrial and aquatic ecosystems. These are then absorbed and stored by wetland vegetation from the surrounding soil and water. Between sand dunes, intertidal beaches and surf zones, sand, biological matter and other materials are also interchanged. The movement of sand ranges from sands that have become stabilized by plants to free-blowing sand (The Nature Conservancy, 2012). Despite strong wind, blowing sand, waves and severe extremes of drought and flooding, many plant species have specialized adaptation to these conditions. Vegetation growth in these environments depends on the structure and mineral composition of the sand grains which provide nutrients for the flora to grow. Other vegetation found in Malta such as the Hard Oligo-mesotrophic waters also depend on the structure of the rock confined to areas of limestone due to its base-rich substrate. Wave action in rock pools and other coastal features may also help increase the nutrient availability for flora. Utilization of incoming nutrients in salt marshes as well as a rapid growth of vegetation provide habitat and food sources for many organisms.

Wetlands in Malta are not only important for their vegetation cover but are hugely important to millions of waterbirds such as herons (Wetlands International, 2012). The most predominant use of sea cliffs is also as shelter and breeding ground for birds. Many of the animals will breed along the shore or cliff and use the rocks as protection against elements.

However, due to the topography, the top of the cliff can support a more diverse wildlife frequently from the surrounding terrain due to its more stable environment. On the other hand, molluscs and other invertebrates such as crabs and echinoderms occasionally survive by sheltering behind rocky outcrops or tucked within tiny crevices (Klappenbach, 2012). Species like the bat also use caves as a shelter, however seasonally as maternity colonies often during the summer periods or as a hibernaculum (shelter) during the winter period (O'Hanlon, 2011).

5.3.2. Negative Impacts on the Geomorphology affecting Biodiversity

Although positive impacts provide a stable habitat, negative impacts can threaten species found within these habitats. The lack of surface waters experienced by karst areas requires fertile soils and adequate rainfall. Karstic soils are also highly susceptible to soil erosion reducing land productivity and having devastating effects on cave fauna (NSW Govt, 2011). The formation of karstic caves is influenced by rainwater and rock within fissures is weakened through leached carbonic and organic acids from the soil. Disturbance of karstic soils should be minimized as much as possible to prevent erosion and increase land productivity. Fires should also be avoided on and around karst preventing limestone from further physical and chemical changes resulting in erosion and loss of habitats.

Fertilisers and pesticides in nearby environments can cause polluted runoff that can travel underground through cracks in the rock possibly rising as springs contaminating the vegetation. Caves, being the basement of the landform also experience potential threats by runoff. All the chemicals from leaking sewage tanks, agricultural pollution and industrial waste flow downhill seeping into these precious geomorphological features often wreaking havoc with the rare life forms present there (O'Hanlon, 2011). Pollution, land use changes, habitat destruction, exploitation of resources, and invasive species in wetlands can also cause biodiversity loss. Therefore, the use of pesticides and fertilisers should also be banned near sensitive karst areas to prevent polluted runoff from travelling underground. Exotic species should also be inhibited from such environments to prevent irreplaceable damage to fragile features.

Pollution, disruptions of sand transport, sea level rise and tourism development also widely affects sandy beaches. These shores are dynamic harsh environments influenced by tides and wave action which determine species diversity, biomass and community structure. Coastal protection works will possibly stop coastal processes functioning and affect the quality of the habitat having a significant impact on these sites.

The most substantial hazard to the flora and fauna is storms and associated erosion. Although predicted temperature changes will not have dramatic effects on beaches, rise in sea level is likely to escalate erosion and thus consequent loss of habitat. The

sea cliffs are another form of erosion landform which may still be active in terms of erosion and receding, subjected to change. These harsh environments are subject to the destruction of waves, wind and salt-laden sea spray. The base of the cliff experiences waves and sea spray playing a vital role in shaping the communities found here, whereas moving towards to top of the sea cliff the driving forces are wind, weather and sun exposure. Erosion is ongoing anywhere that waves batter rocky coasts and in those zones of weakness contained in sea cliffs rock is removed at an alarming rate. Fissures that are formed begin to widen and deepen from the force exerted within this confined space. Suspended sand and rock particles acting as an abrasive force, add to the hydraulic power of the waves. The most tenacious of animals are the only survivors at the base of the cliff, prohibiting any other form of life due to the striking by the surf (Klappenbach, 2012). The rdum and boulder scree also limit the amount of animals inhabited in these areas due to the rough terrain, winds and weather conditions which tend to vary. These factors make it a nuisance for land dwelling animals, therefore the most common animals found in this type of habitat are birds.

Valley systems are prone to storms which aggregate flooding thus creating problems of flood damage. A high storm water run-off will increase soil erosion near the watercourse thus destroying several habitats. There is the need of clearance to allow fast drainage during intense rainstorms.

Rock pools also offer various challenges to the hosted habitats as they require high adaptations to cope with a fluctuating environment. A change in water temperature, salinity and oxygen content put pressure on species. However, species in these habitats must endure to survive strong currents, huge waves and in low tide situations, exposure to sun and predators. An embryonic dune is also seen as a hostile environment for plants because of the salinity, lack of humus and pH of 8-9. It is also a very dry environment and the rapid drainage and exposed nature of the site make it difficult for plant growth. This is a highly dynamic natural community based on sand. Sea caves and karst caves may abound with life however lack of light, interference of waves, flooding and littoral erosion also limit and put pressure on the life of species living in these environments. Also due to their fragile nature of the ecosystem as well as their isolation from the surface and one another, caves harbour endangered species.

Human interference is not least to be mentioned as it is one of the greatest influences on shaping the landscape it is today. Human built structures or activities which alter the sand budget or impede natural sand transport also lead to severe erosion, usually of a permanent nature. Off-road vehicles, beach cleaning, ecotourism and trampling are all direct negative impacts on the sandy beach. With a highly dense coastal human population in Malta and a growing tourism rate, pressures on the shore are increasing with the continuing hardening of surfaces in and above the dunes causing damage. Vandalism such as spray paint on the walls of the caves can disturb the bat species as these depend on such structures, garbage and other debris deliberately left by humans can also be of a nuisance to other species. Due to the abundance of fish, fuel and water, wetlands are vulnerable to over-exploitation (The Ramsar Convention on Wetlands, 2012). Wetlands are targeted for drainage and conversion when seen as unproductive or marginal lands. In Malta, such a water-scarce region, diversion of water can negatively impact healthy wetlands. Diversion of water is typically brought about by population growth, industrial activities, irrigation and dams (Wetlands International, 2012). Another irreplaceable however, both physical and chemical changes occur when limestone is exposed to fire it causes it to fracture and fall apart (spalling) also inducing a chemical reaction in which the rock surface disintegrates once exposed to extreme heat. Such physical and chemical changes can result in increased erosion, lower land productivity and loss of habitats.

5.3.3. Biodiversity shaping the Geomorphology

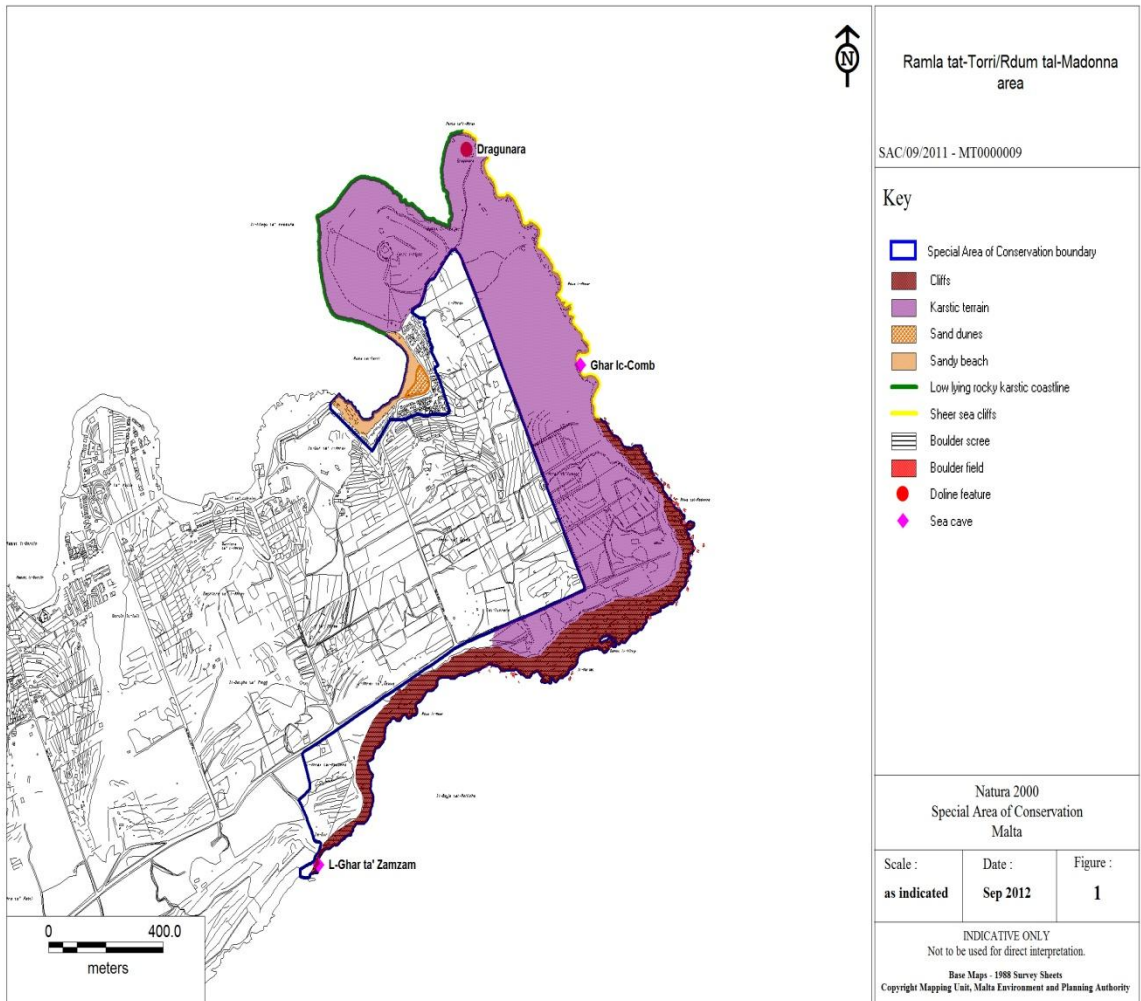
In certain cases, the role of biodiversity within the environment can be seen as stabilising its own habitat by shaping the geomorphology. Such an example can be seen by vegetation that can help stabilise a sand dune by preventing its movement with prevailing winds. However vegetation cover is sparse with perhaps 80% of the dune being exposed sand. On the other hand, although winter storms can sometimes wash away this dune it eventually builds up again in the summer. Therefore it is vital for the continued supply of new sand from the beach plain into the dune system for the continued existence of this community, even if this sand is derived from within the same system (JNCC, 2012).

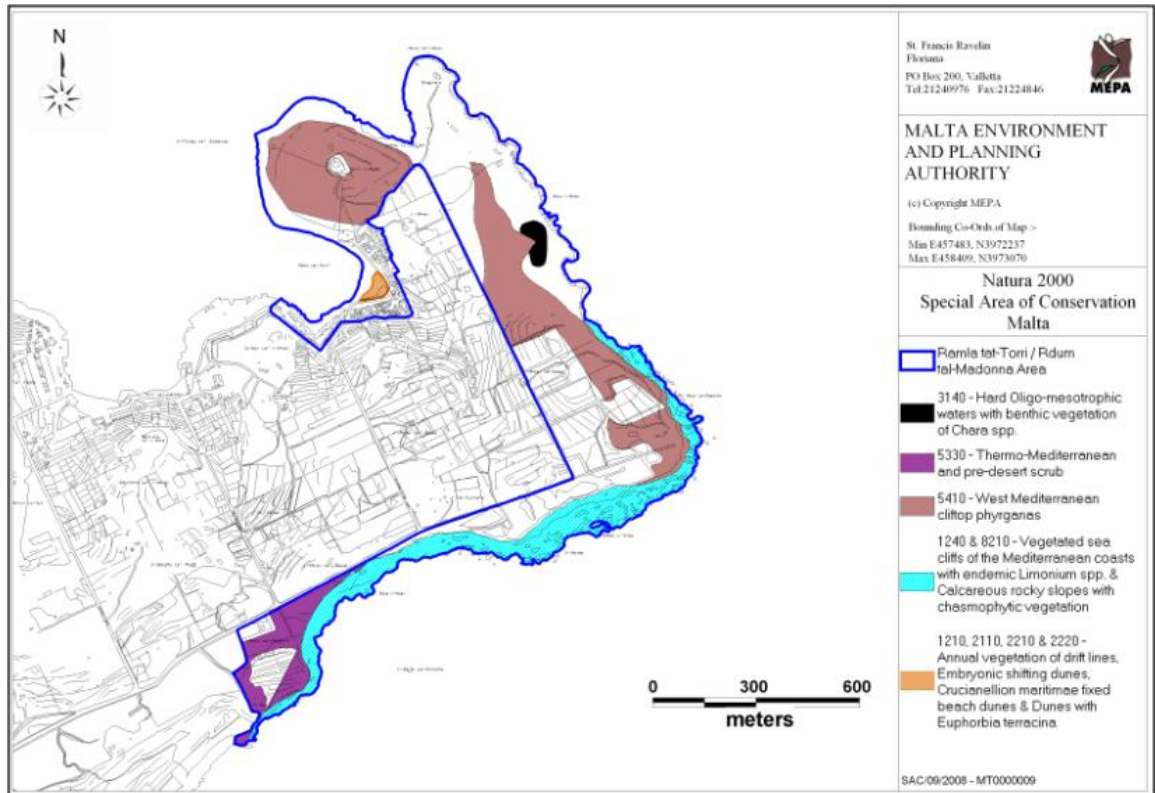
Vegetation in wetlands can act as physical barriers to slow water flow and trap sediment which supplies most nutrients. Vegetation cover can also act as an indicator

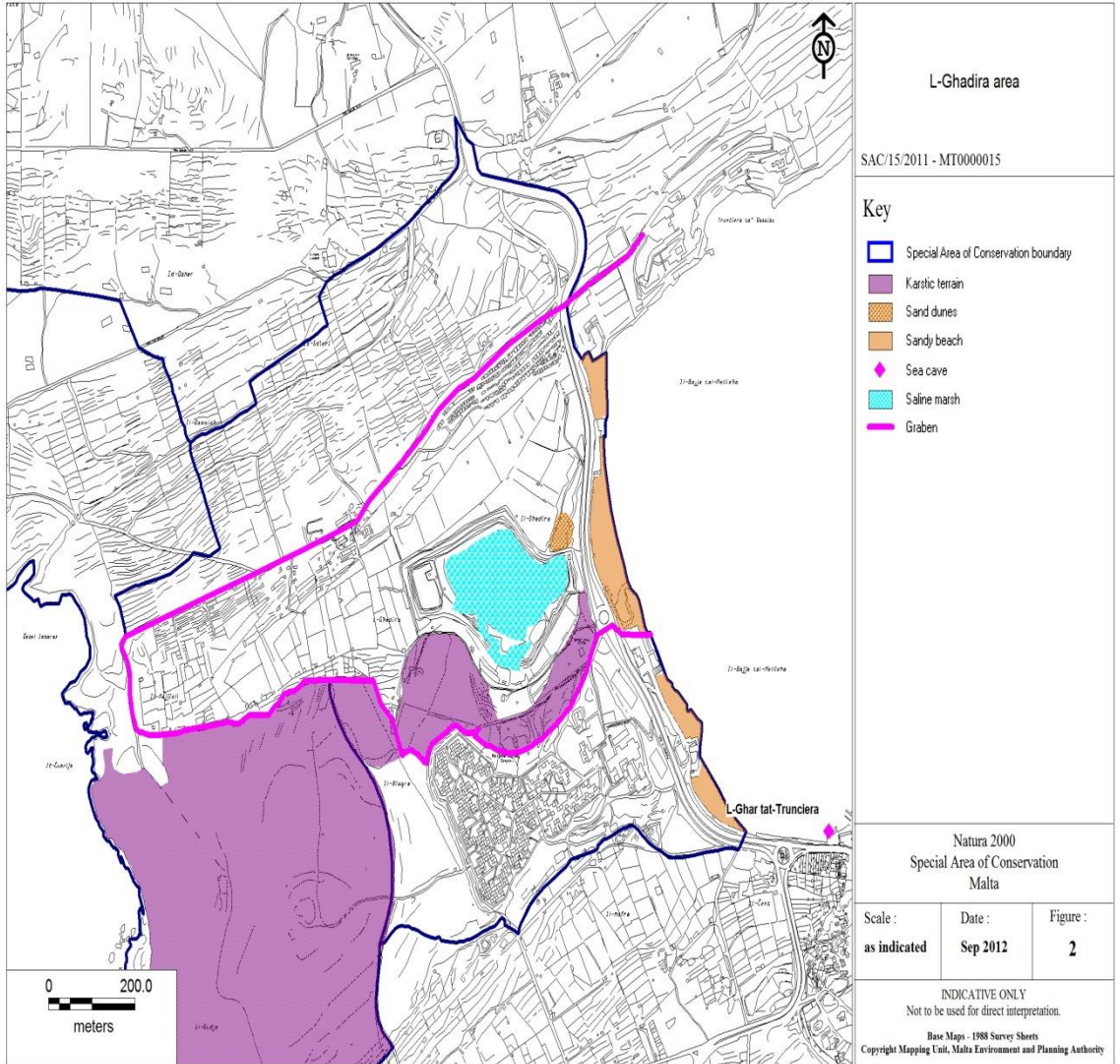
on the presence or lack of activity on a sea cliff. As one descends, the harsher the conditions become and therefore flora and fauna find it more difficult to adapt to such an ever-changing environment.

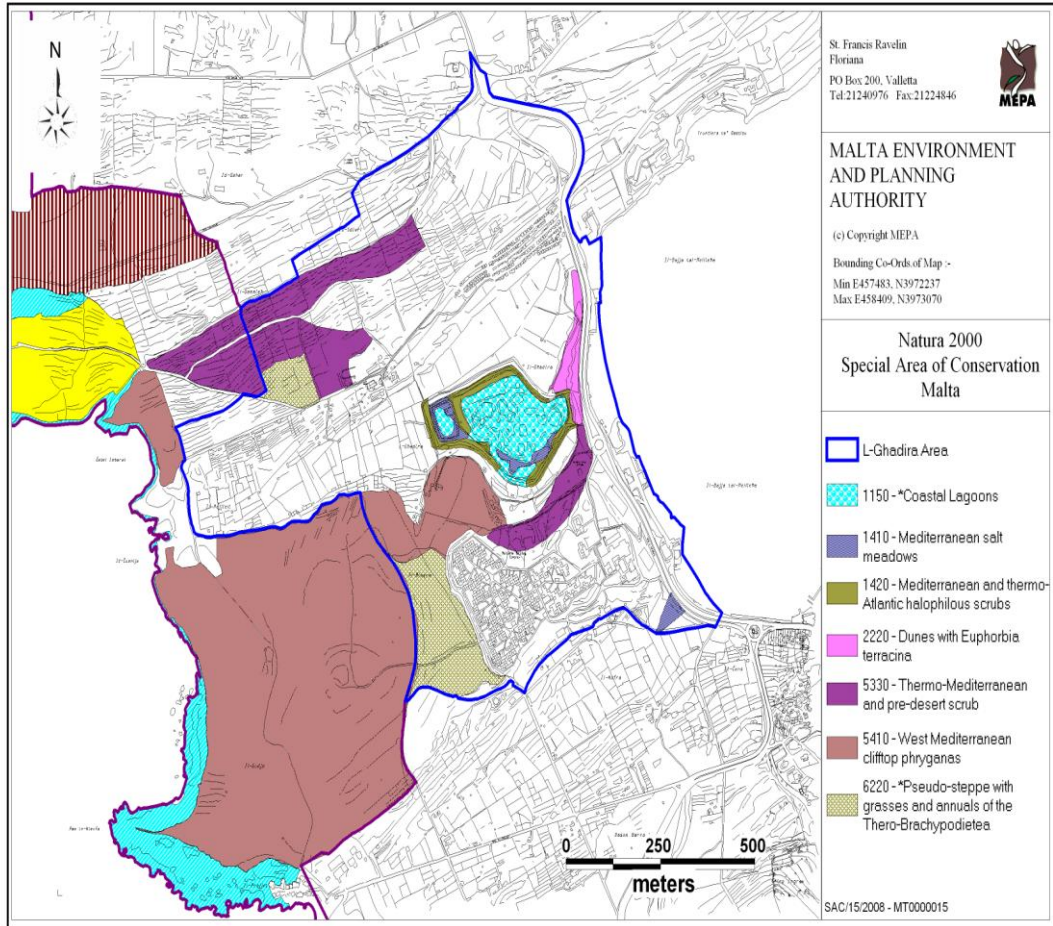
Marshes are very important in preserving the quality of surface waters as vegetation and microorganisms use excess nutrients that can otherwise pollute surface water such as nitrogen and phosphorus from fertilizer for growth (EPA, 2012).

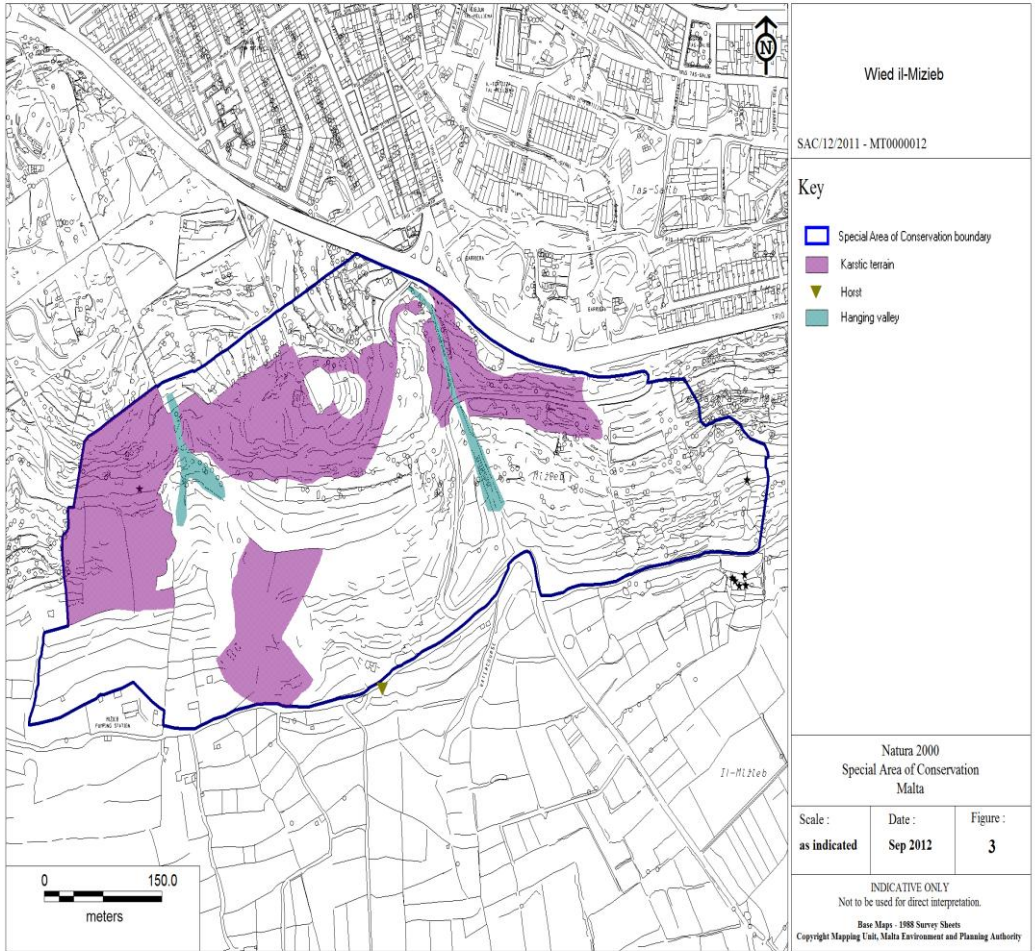
Physical and chemical characteristics of karstic environments may be altered by non native plants also causing irreplaceable damage to fragile features found in caves. Life within the sea caves can be seen as a similar process. In this case, drilling of sea urchins into the rock removes considerable bedrock from the floors also assisting the formation of caves.

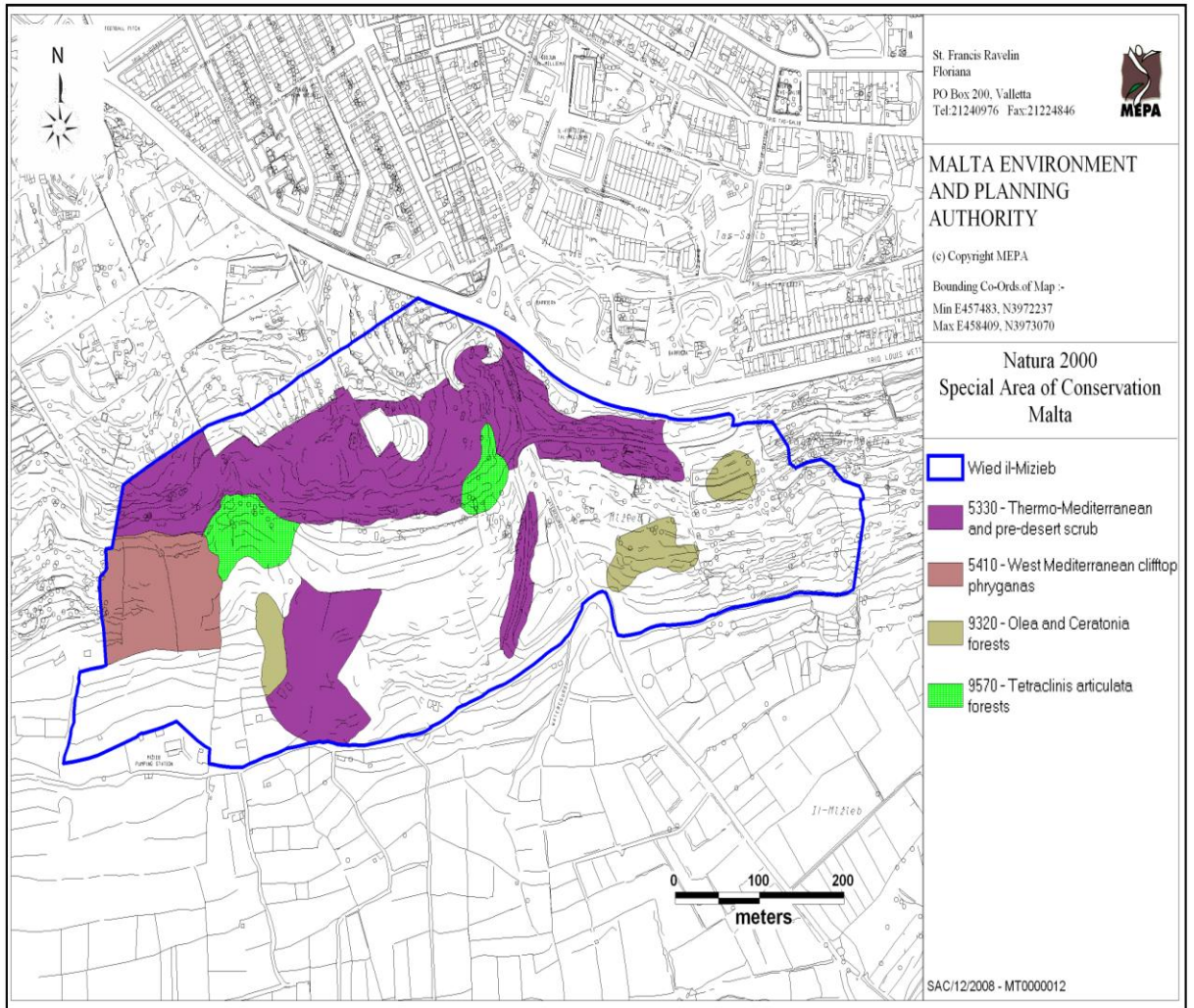


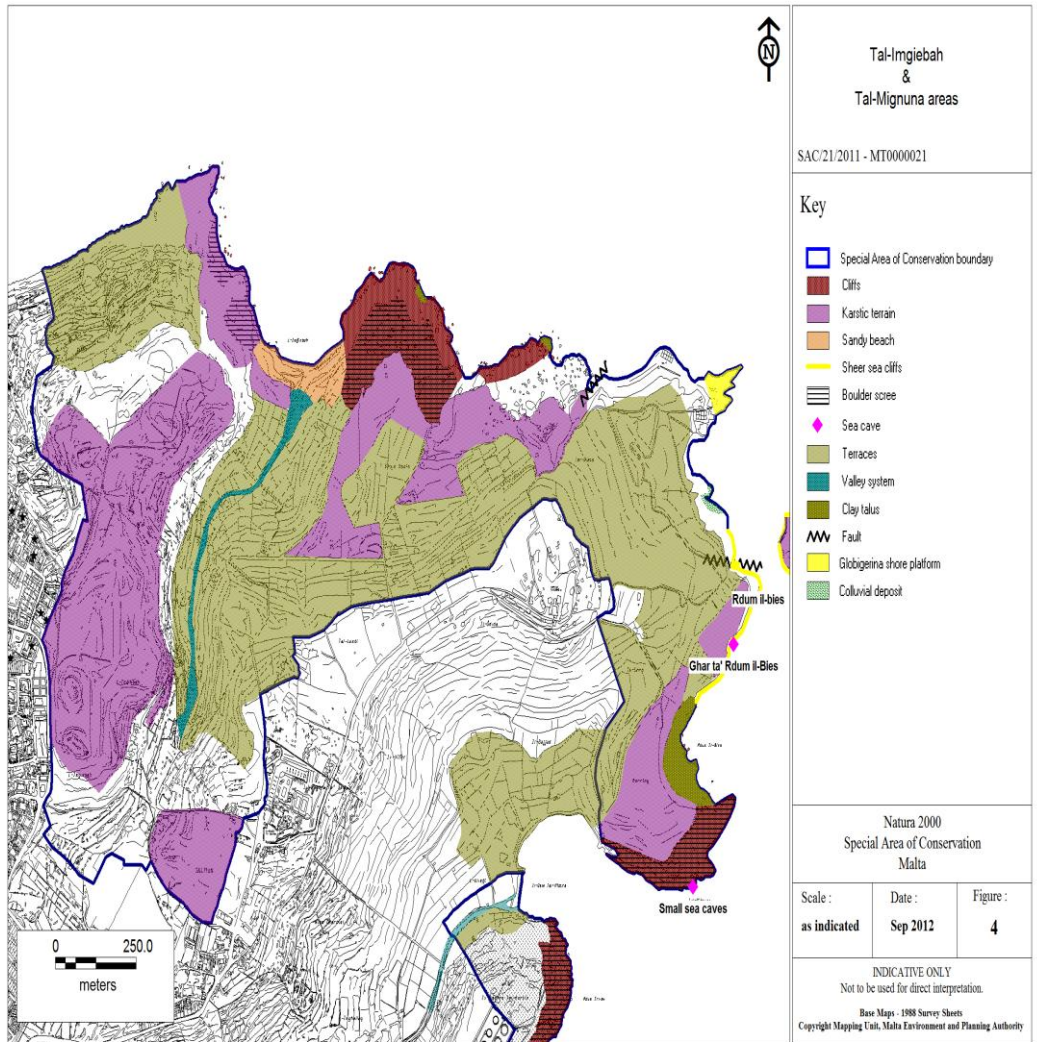


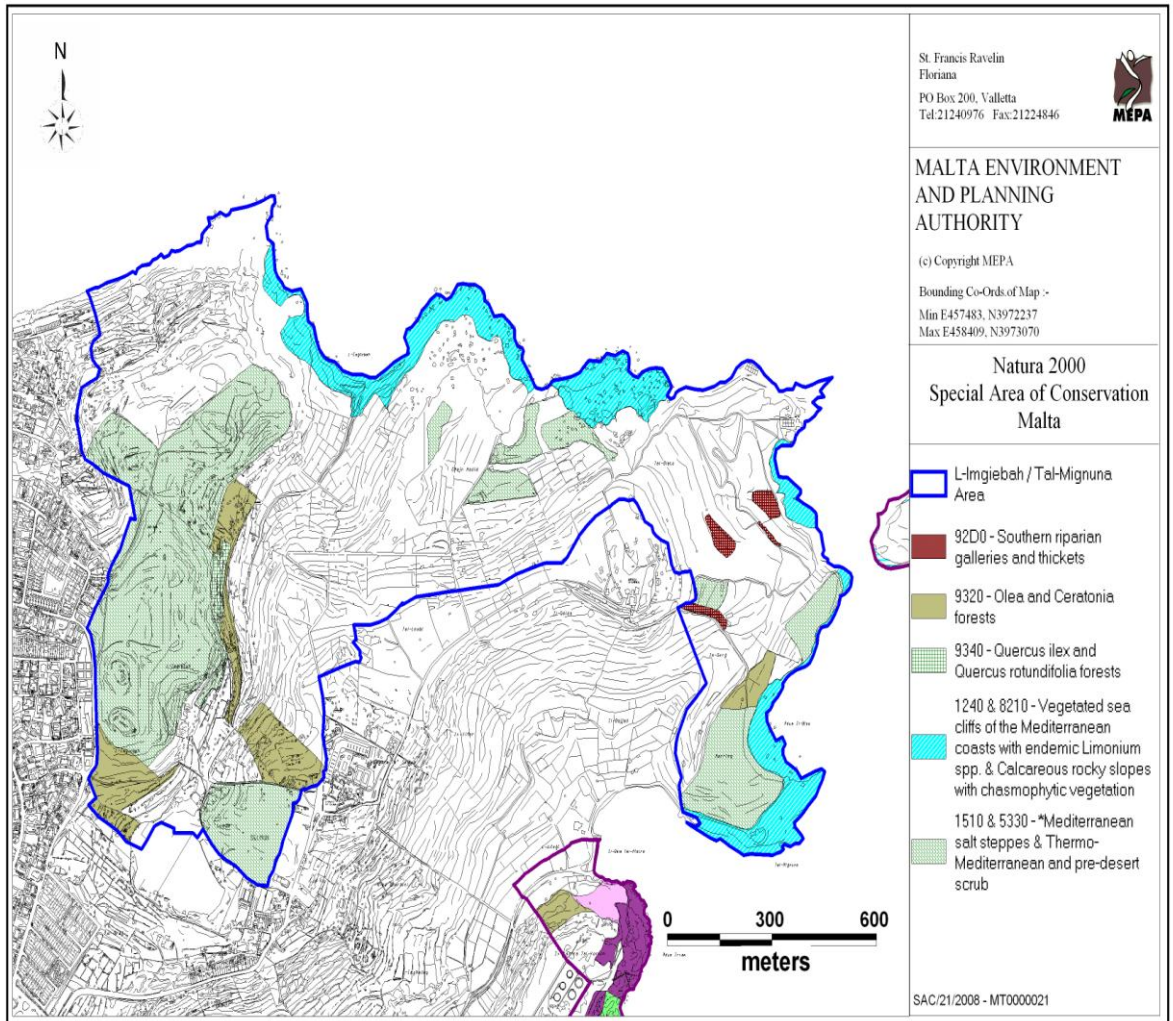


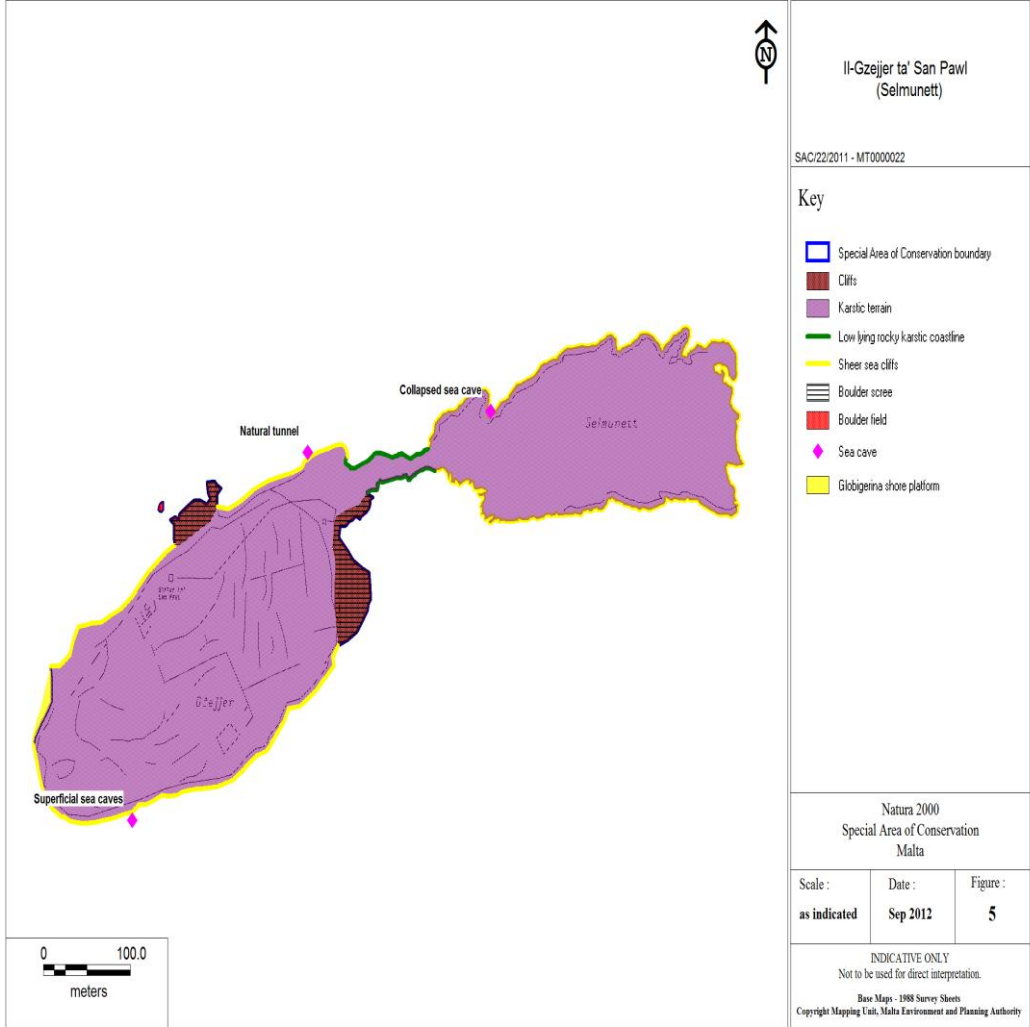


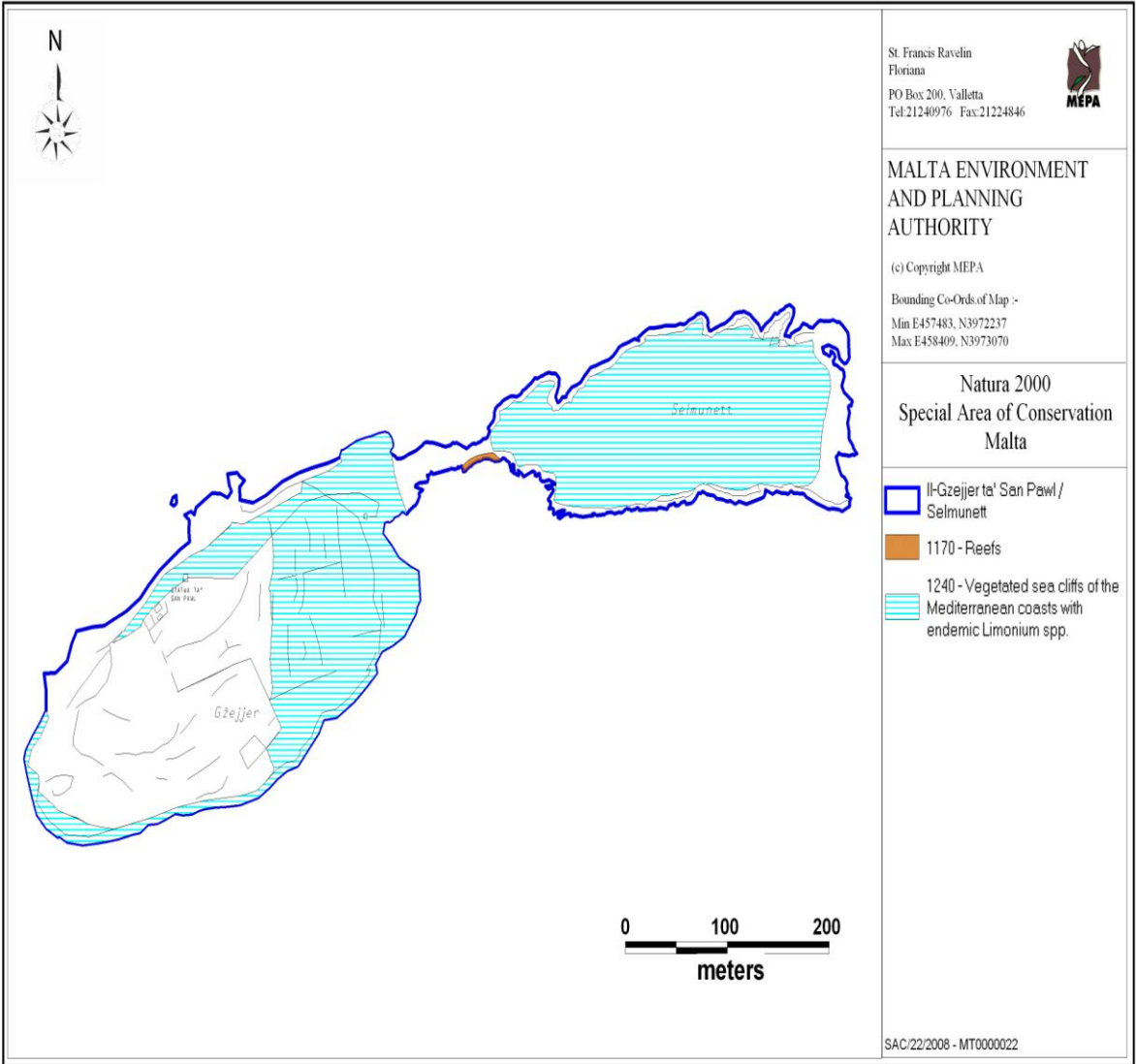


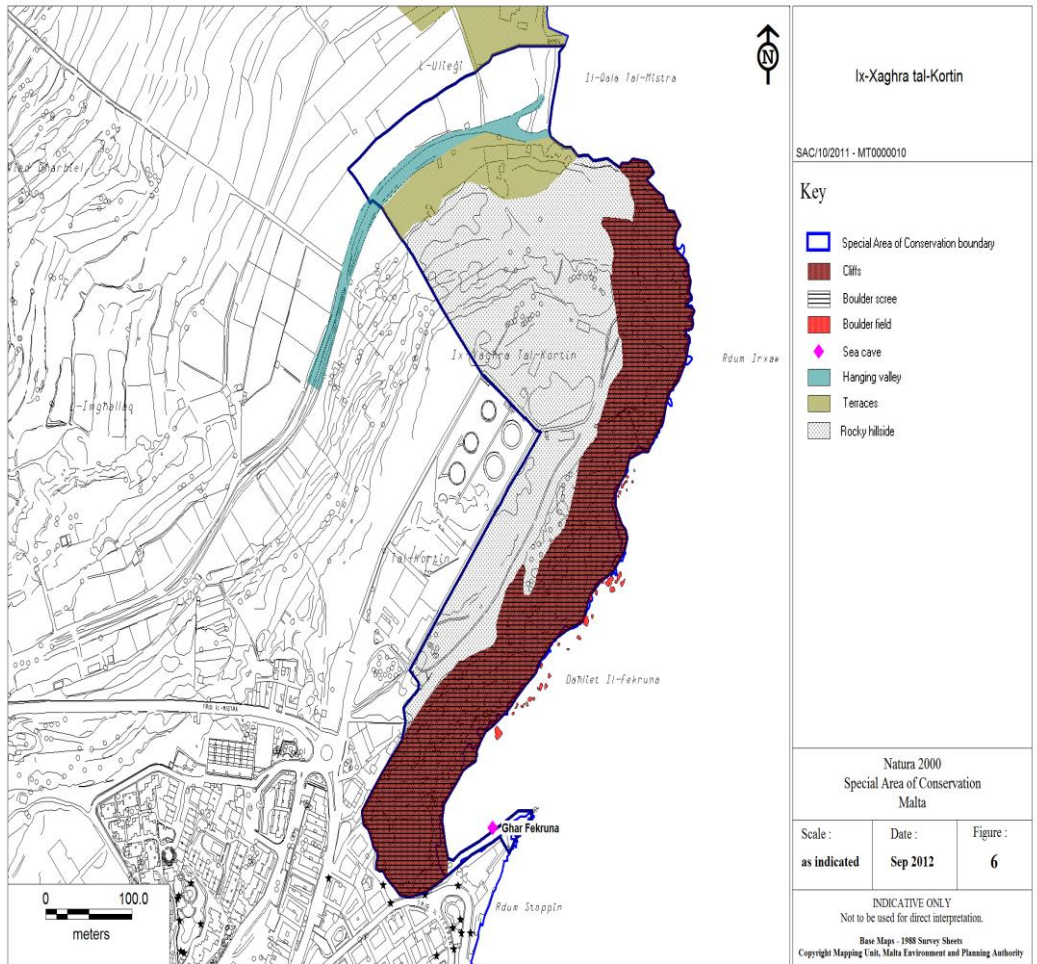


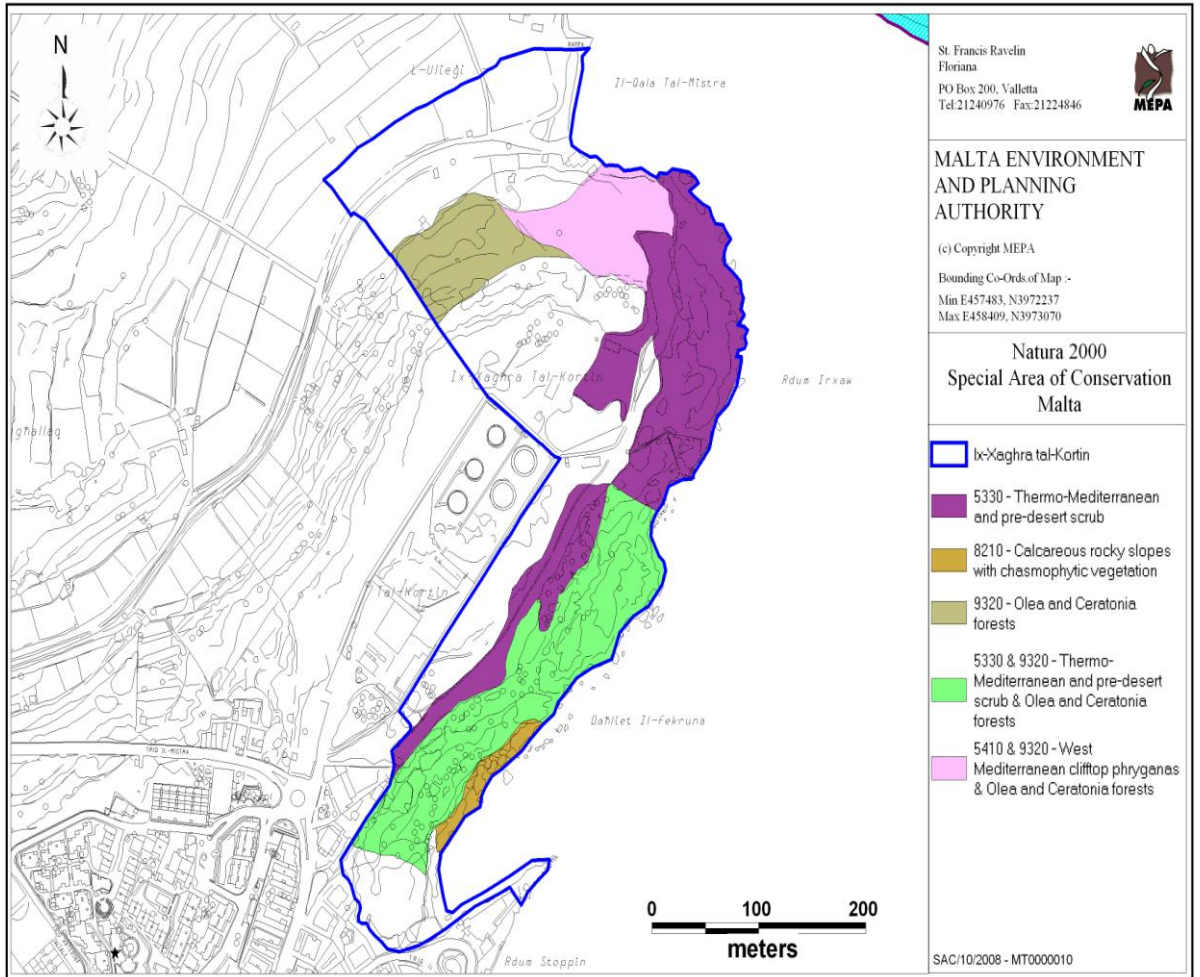


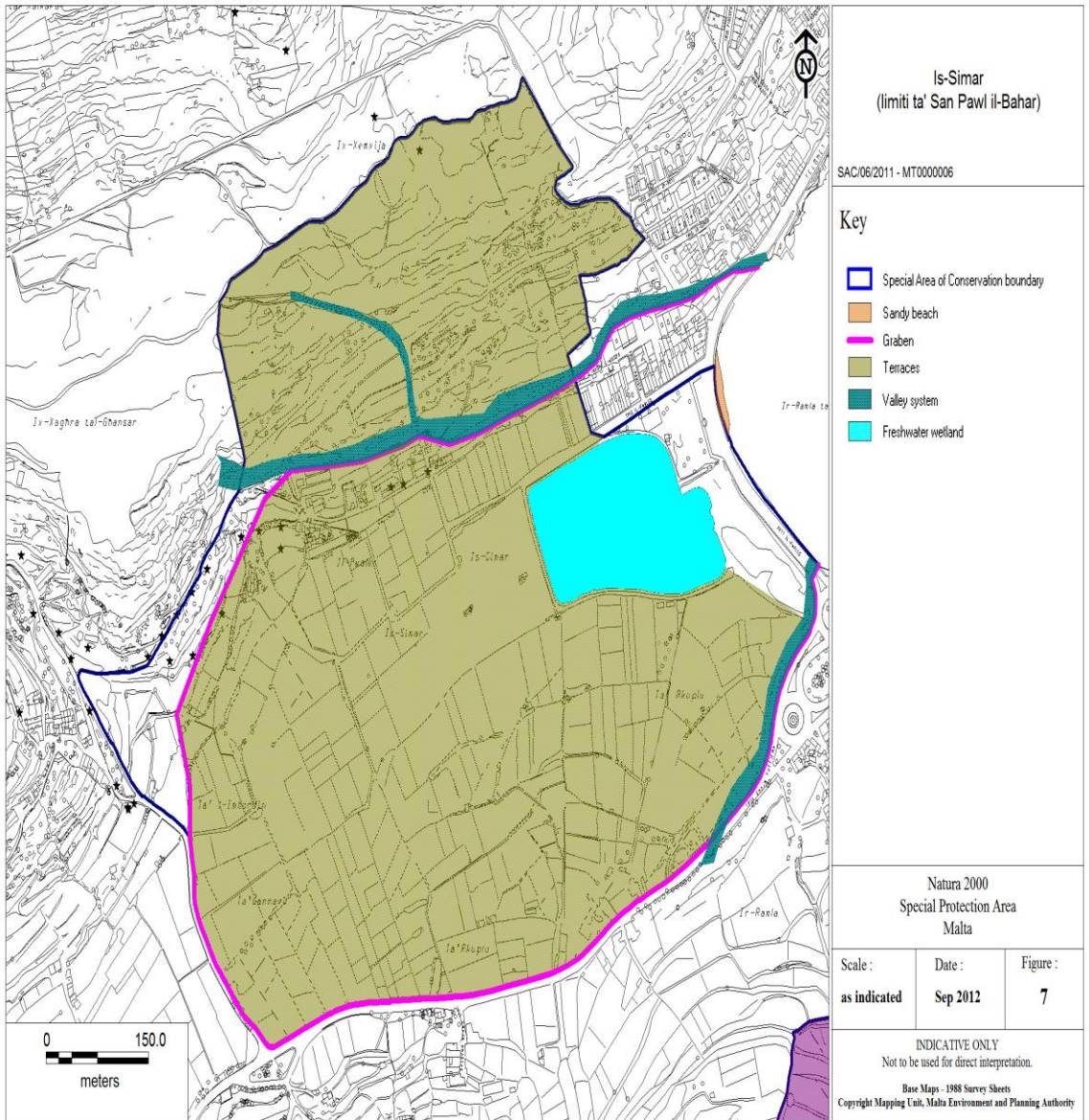


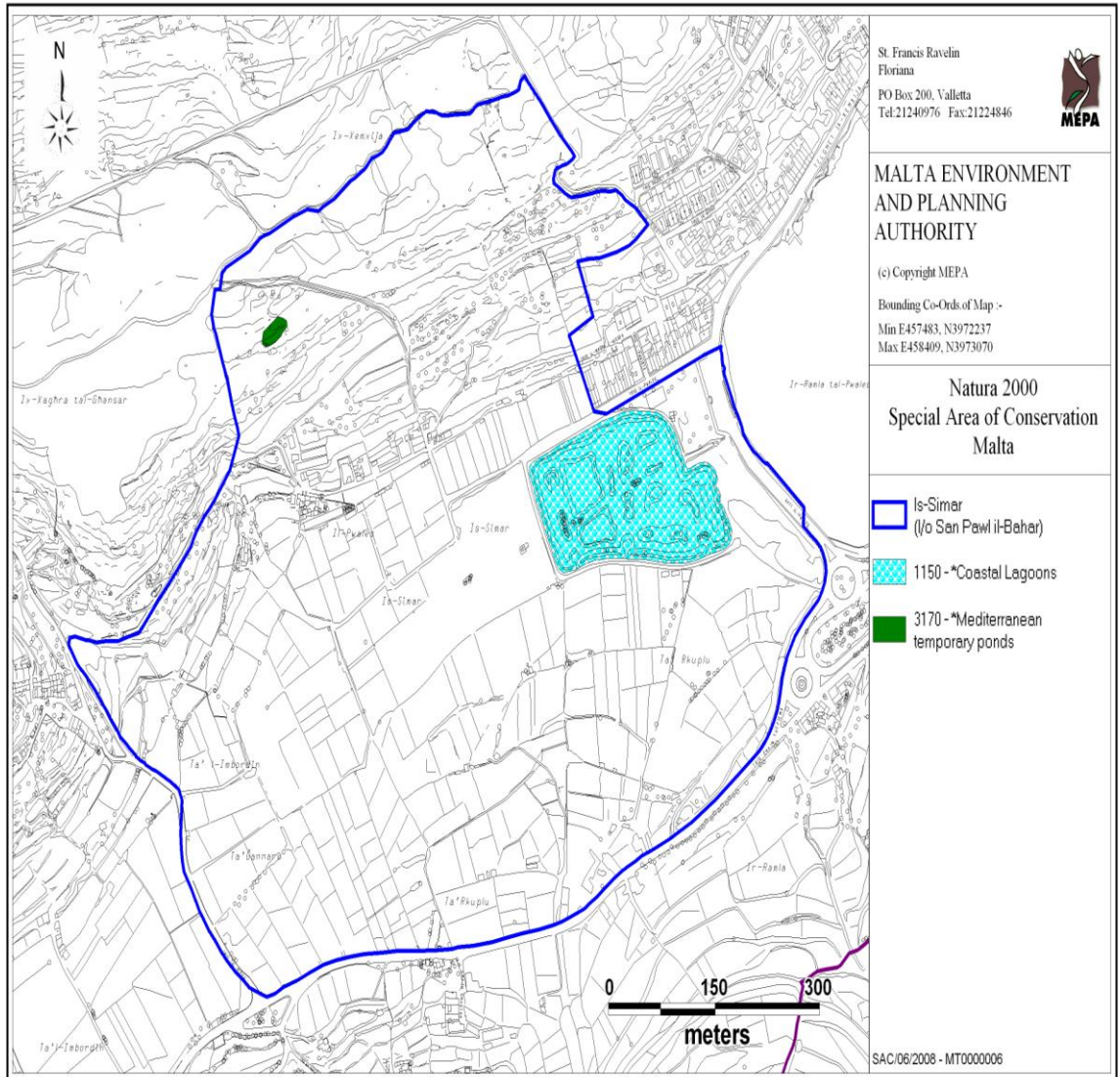


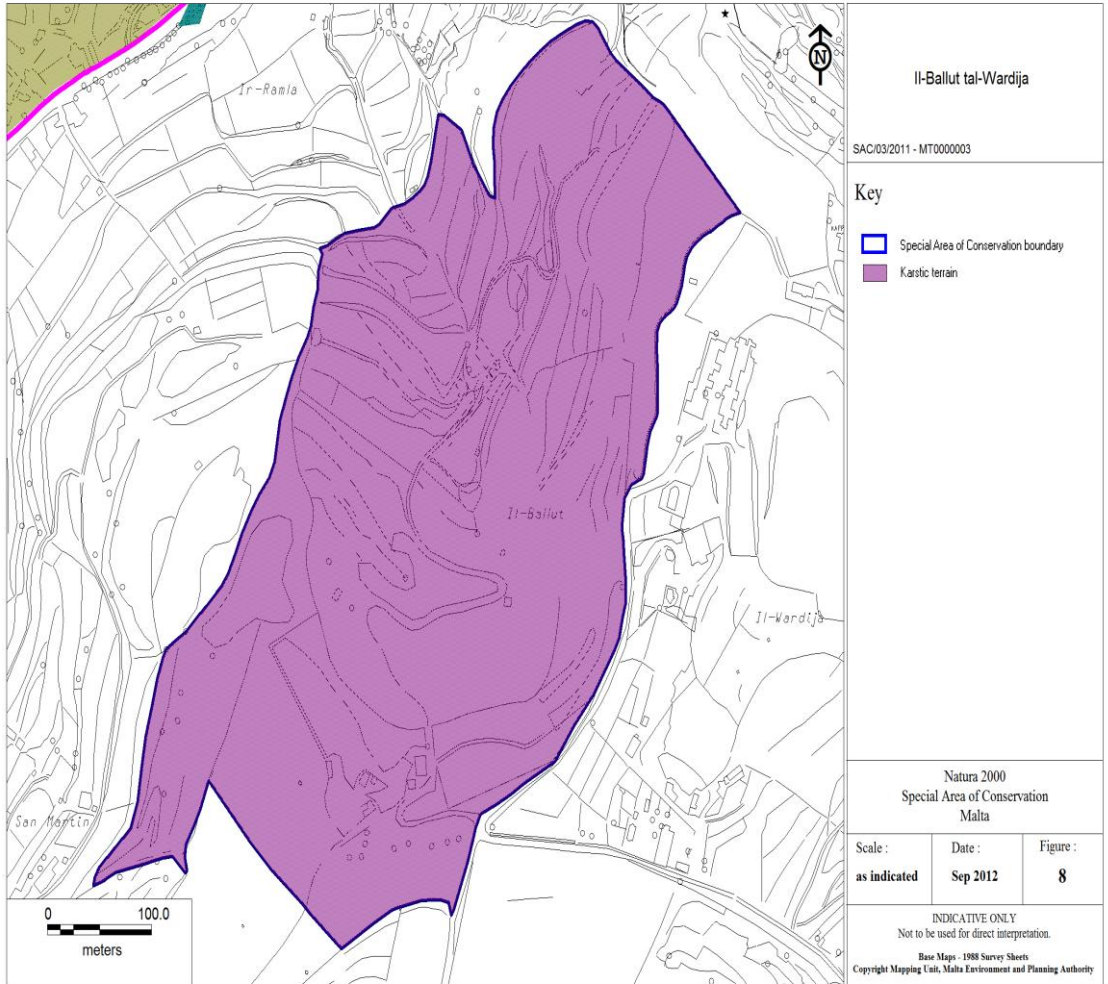


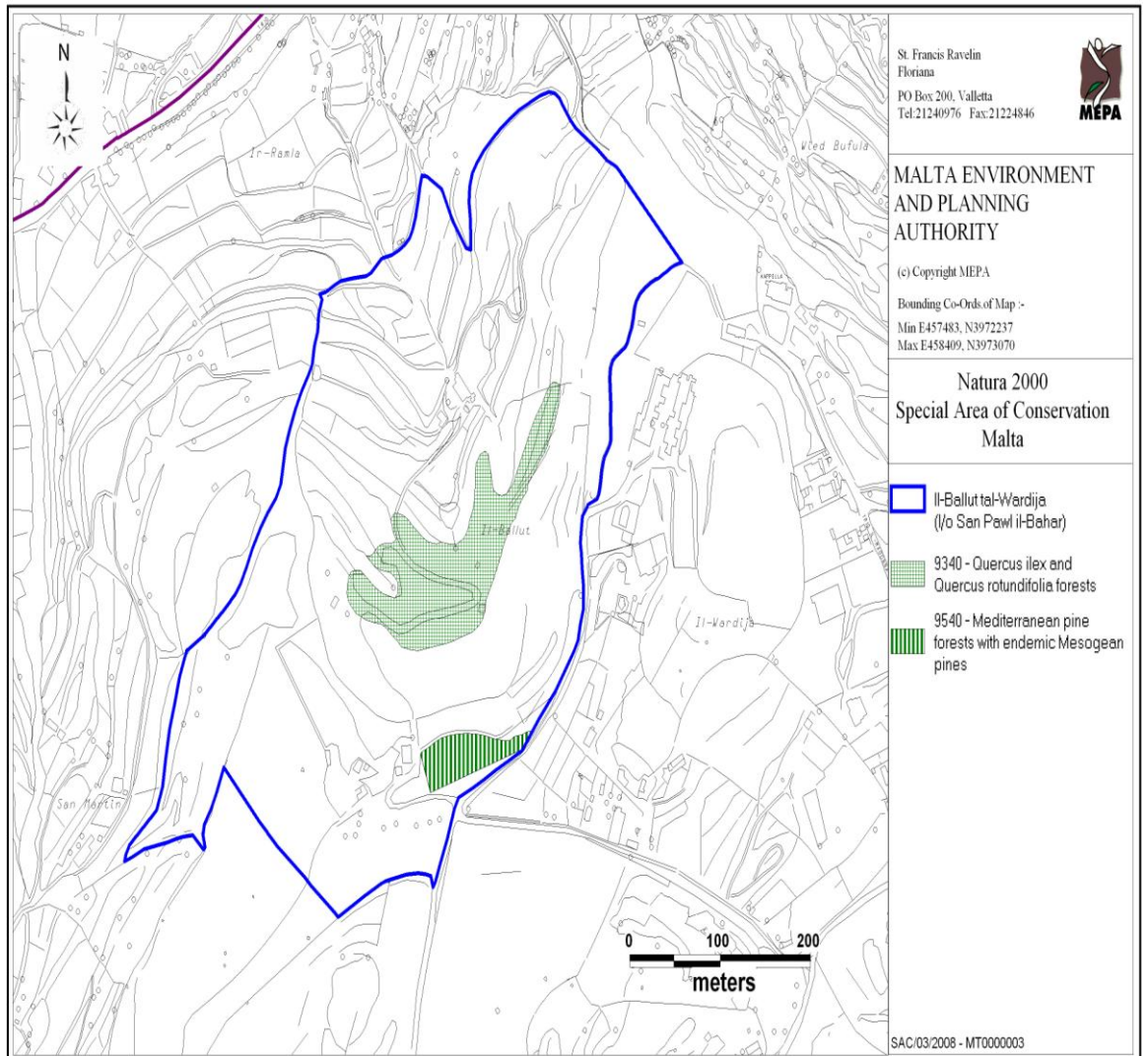


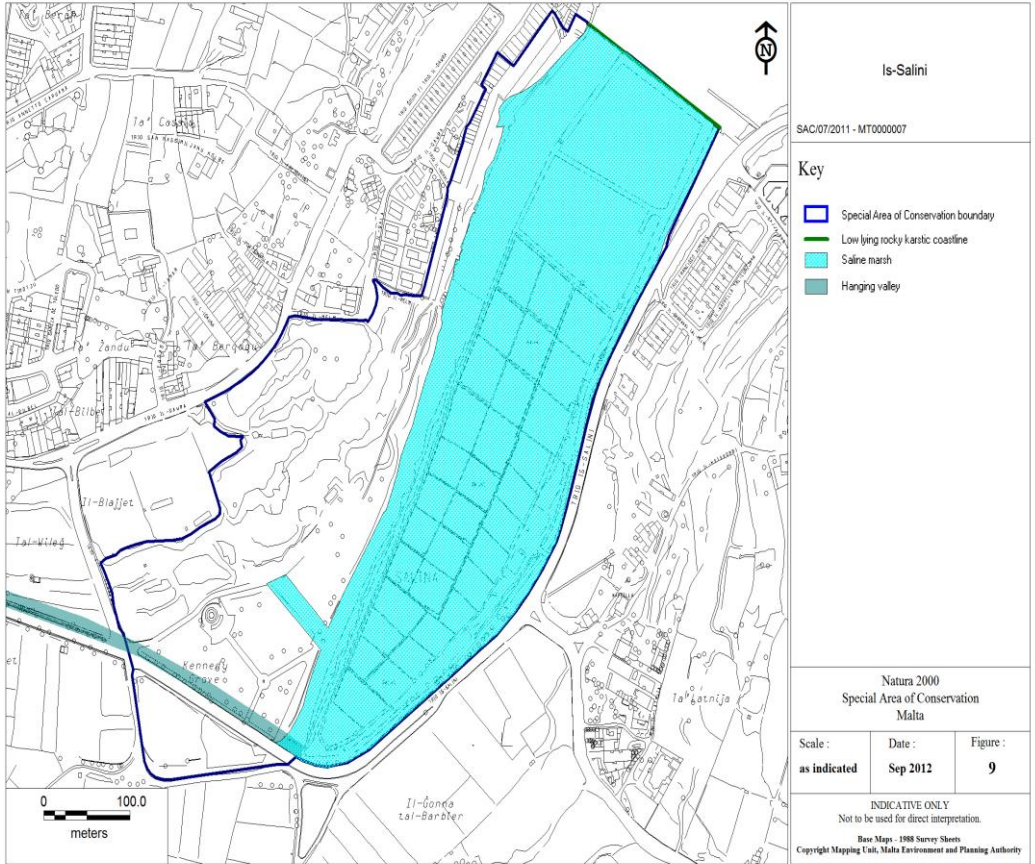


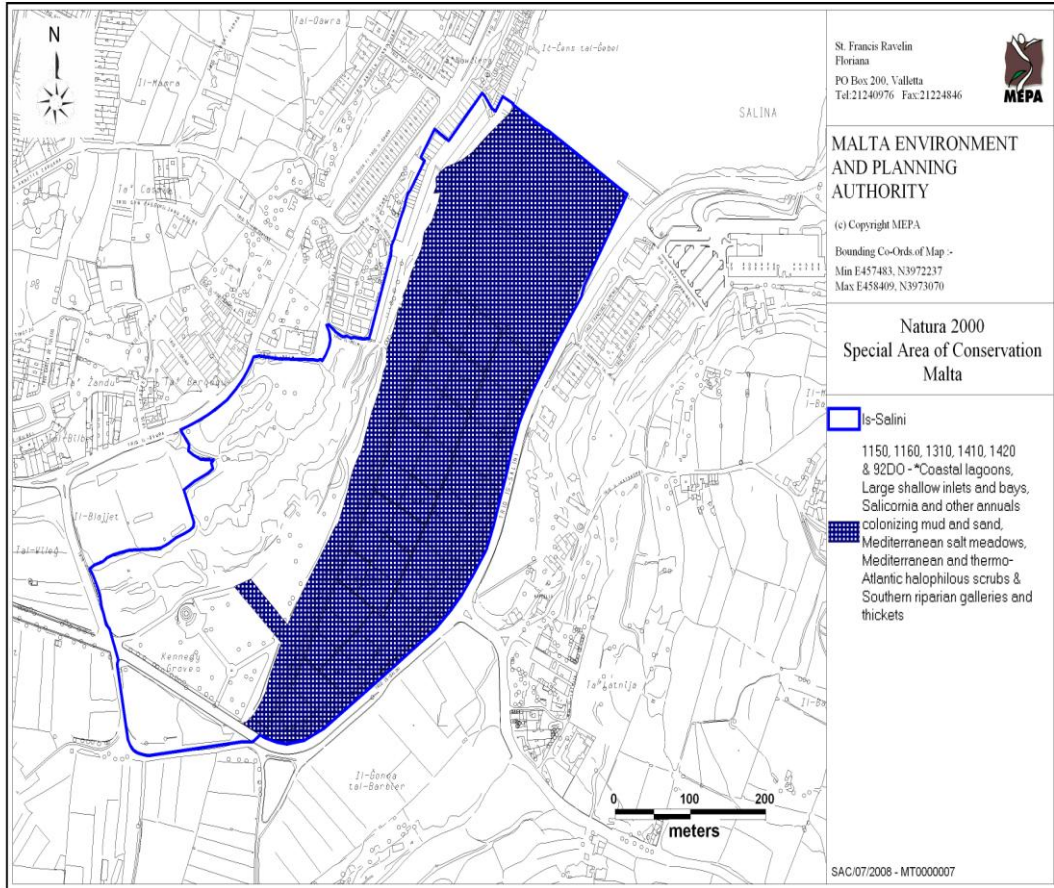


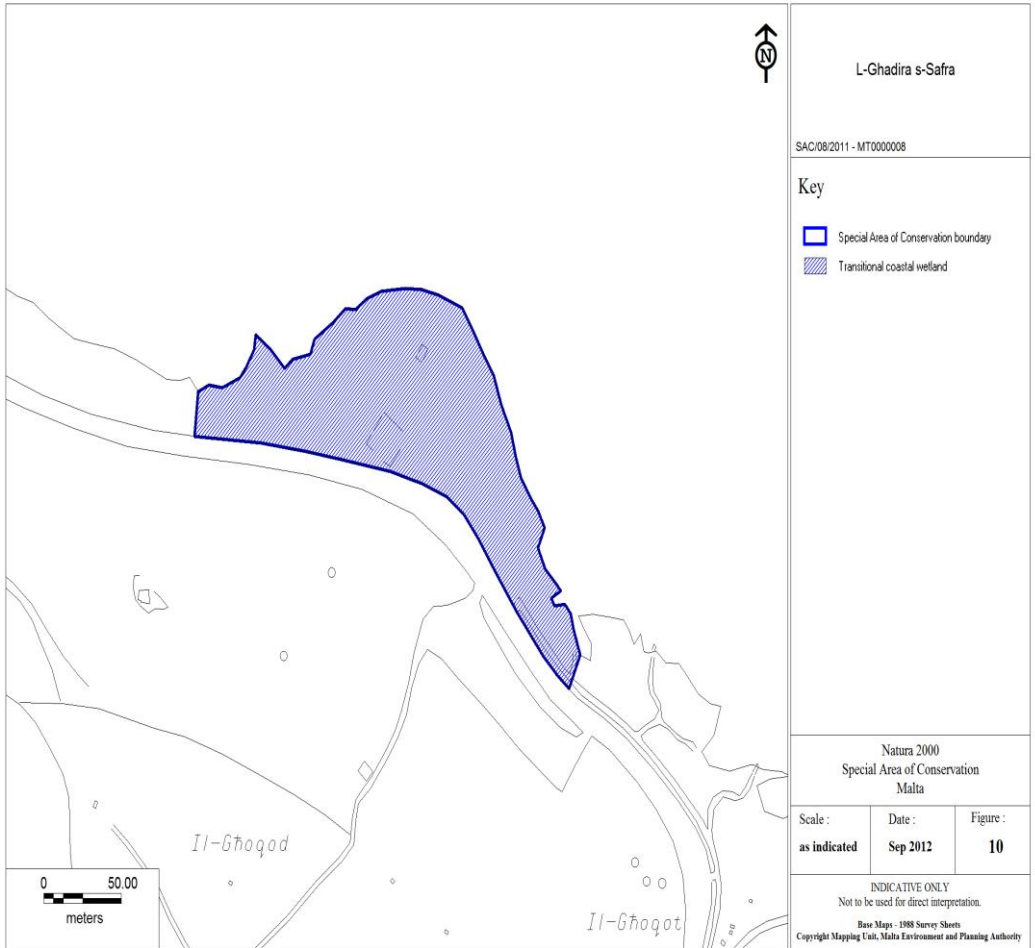


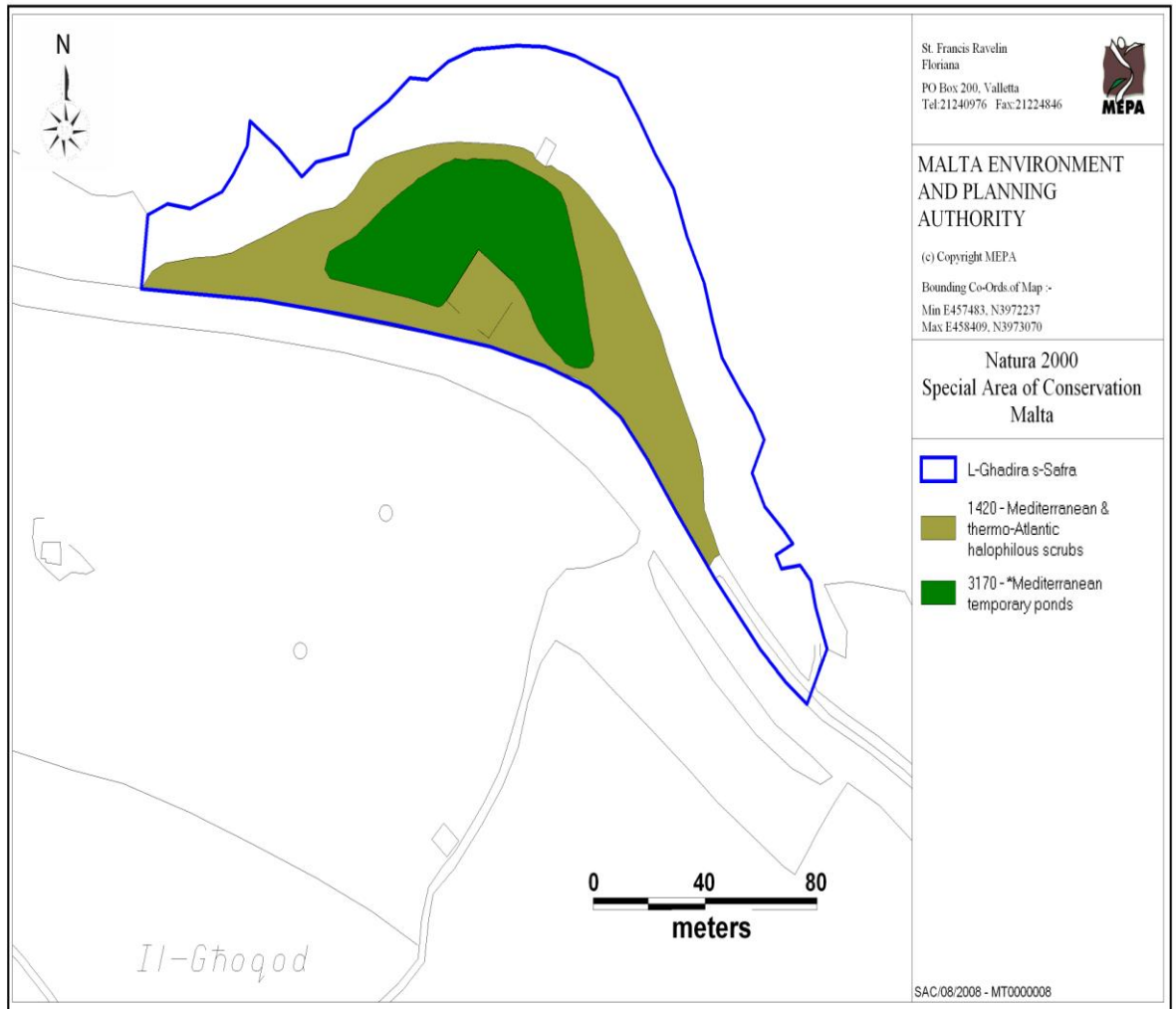


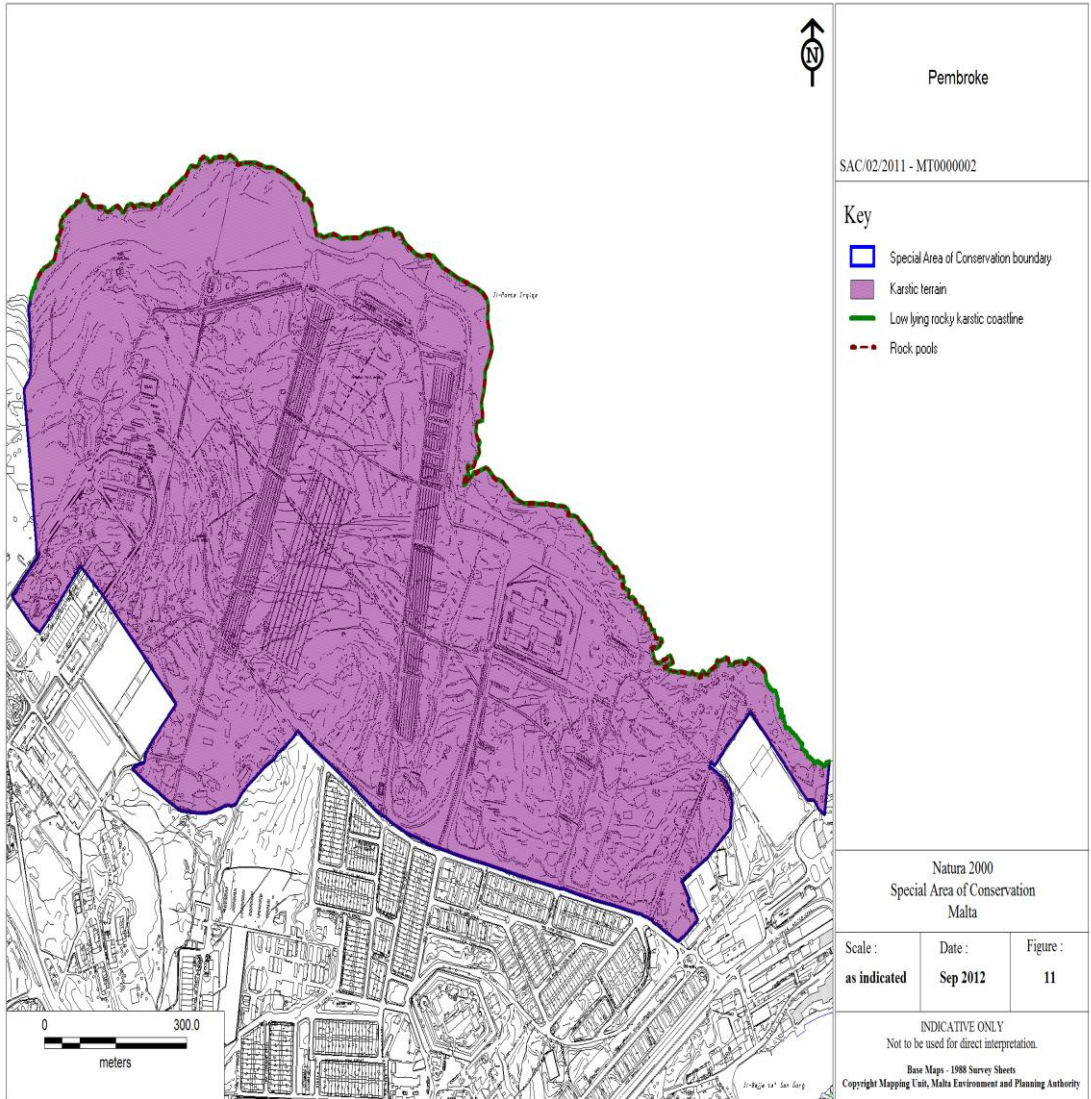


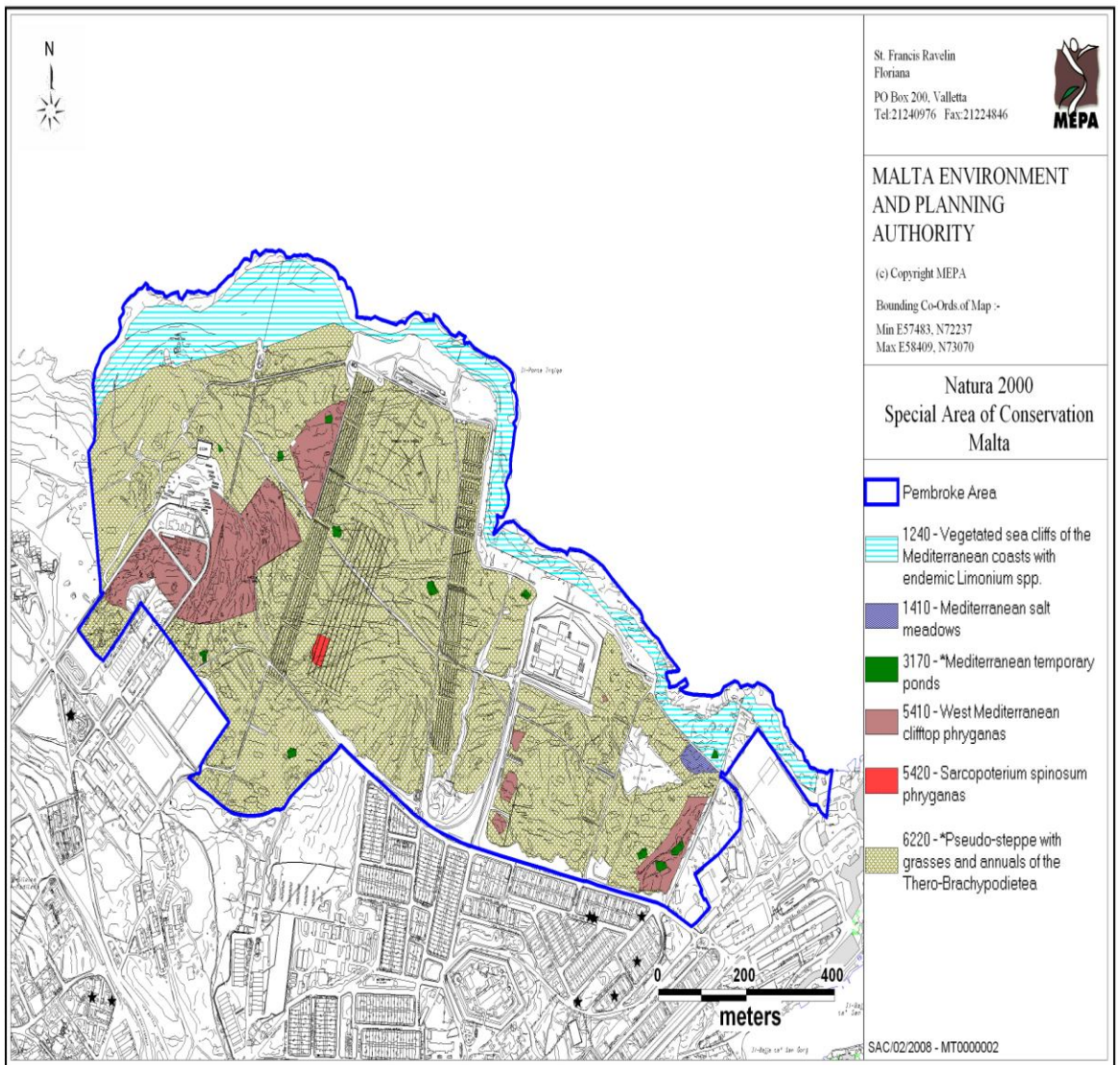


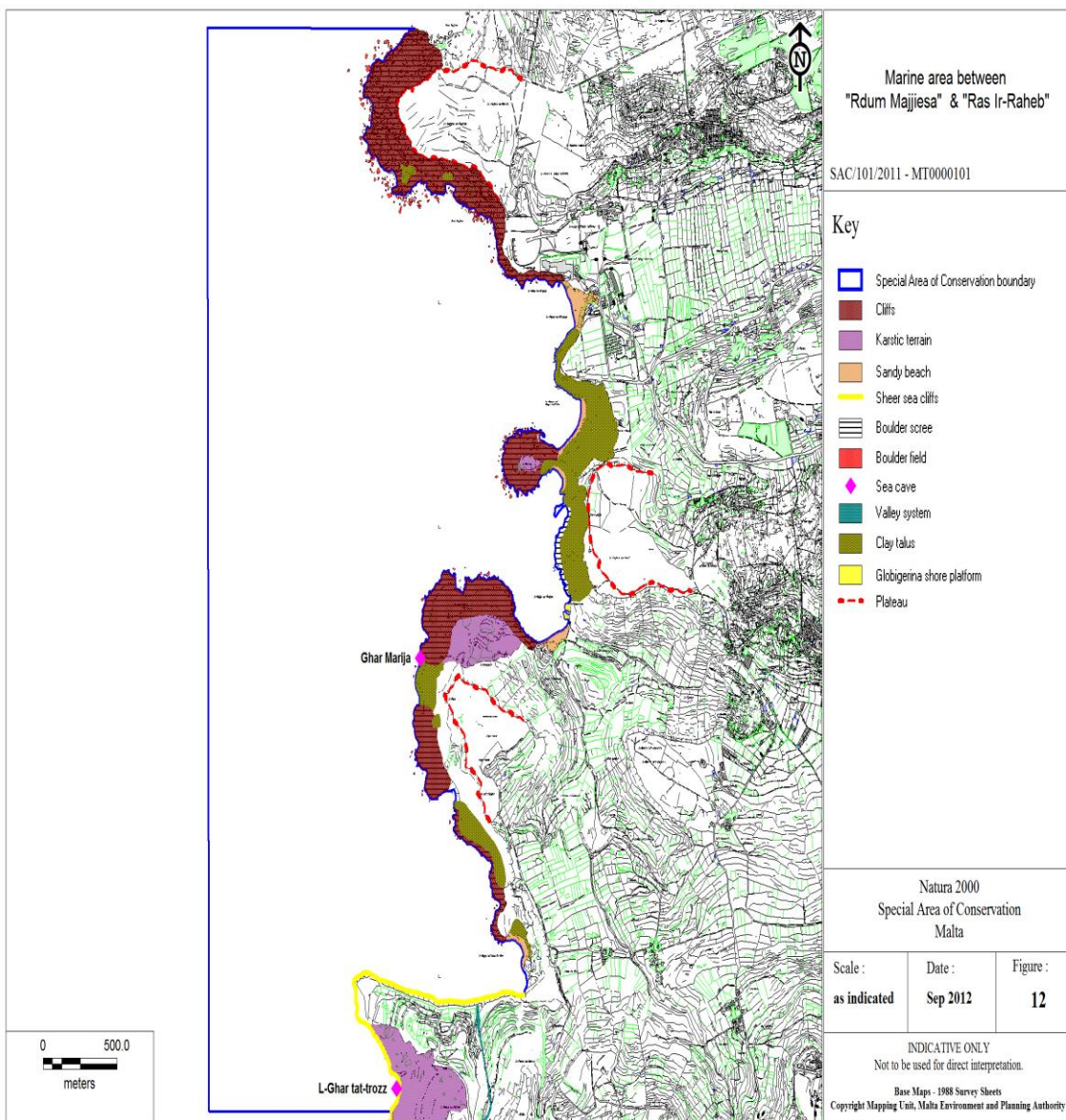


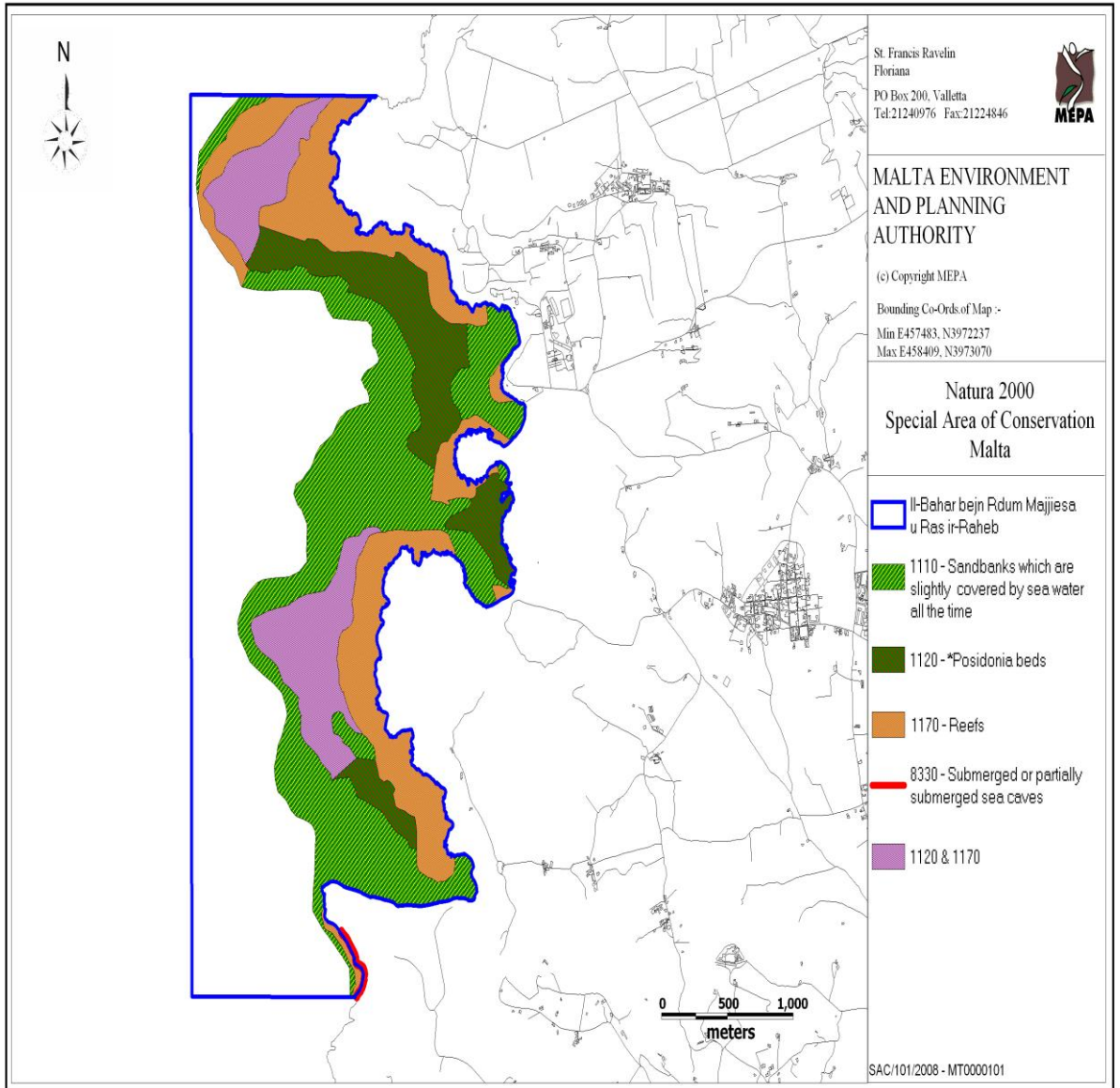


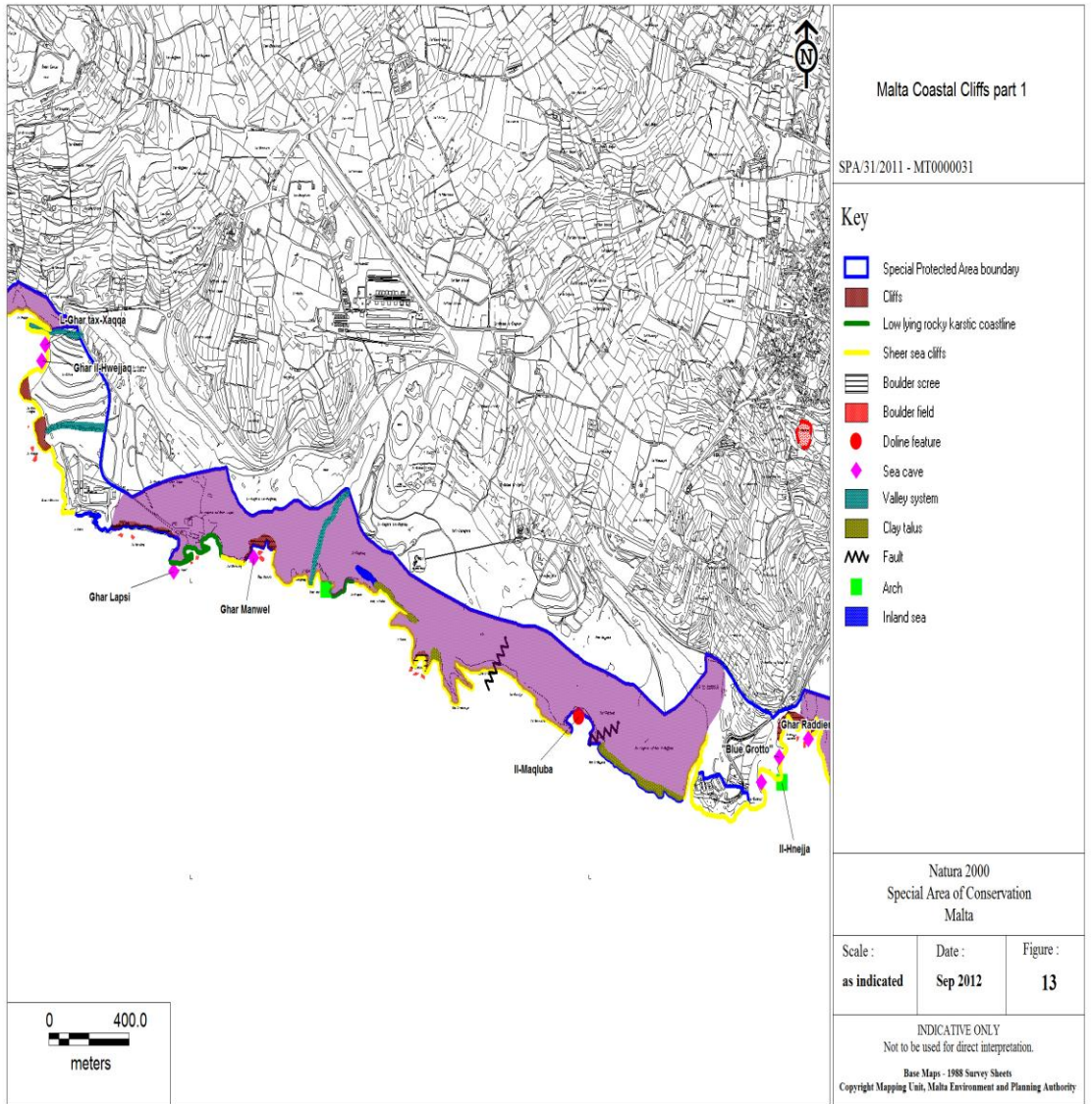


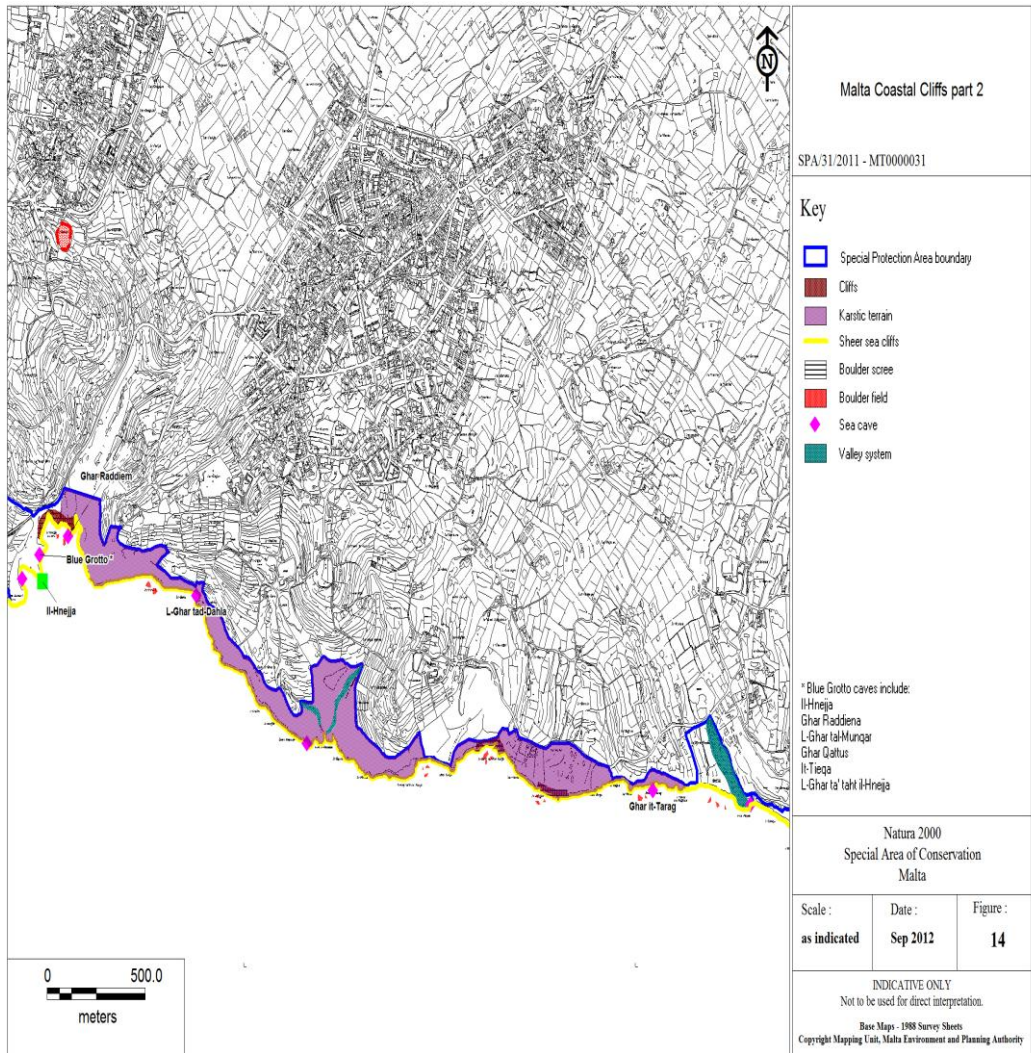


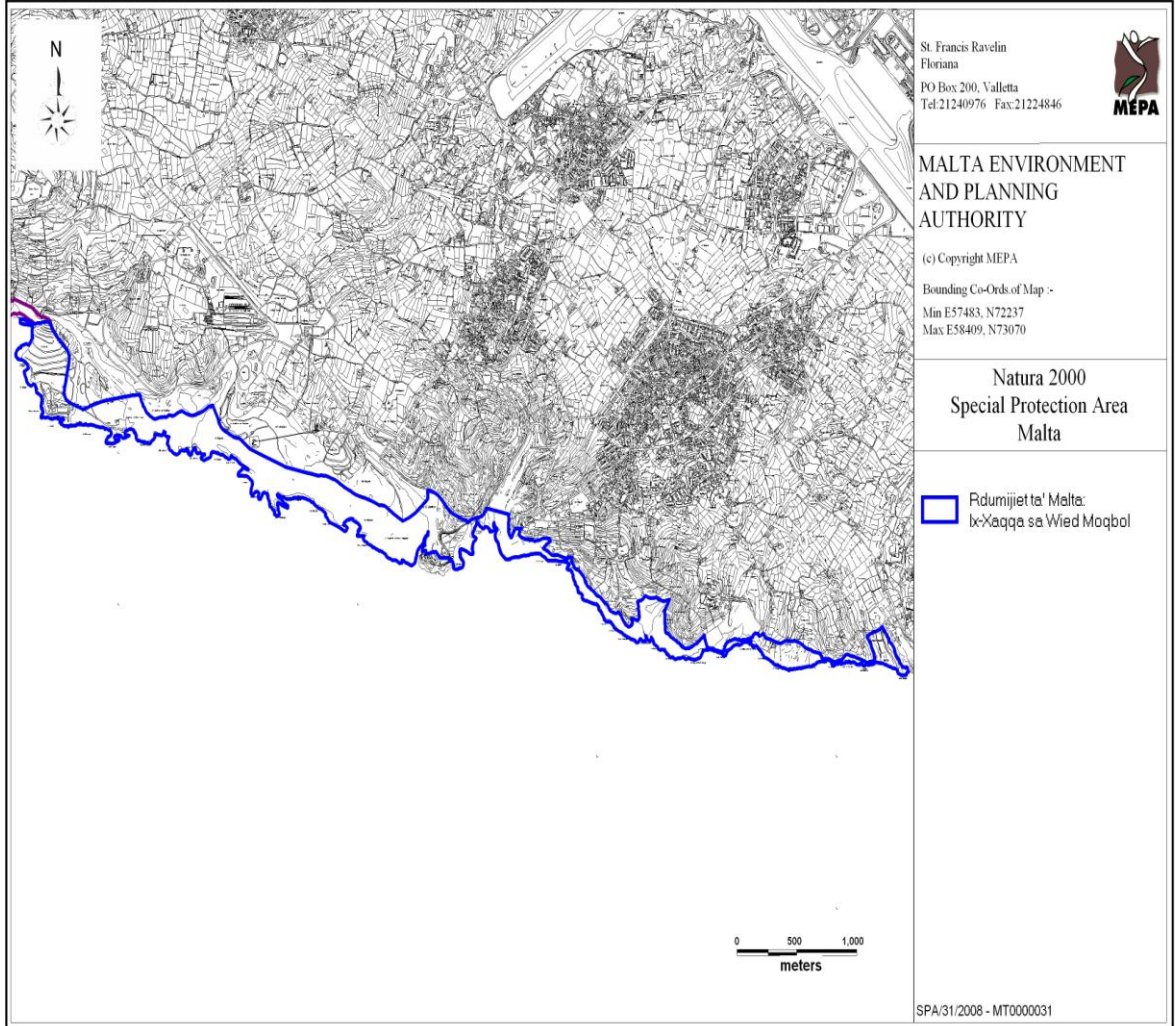


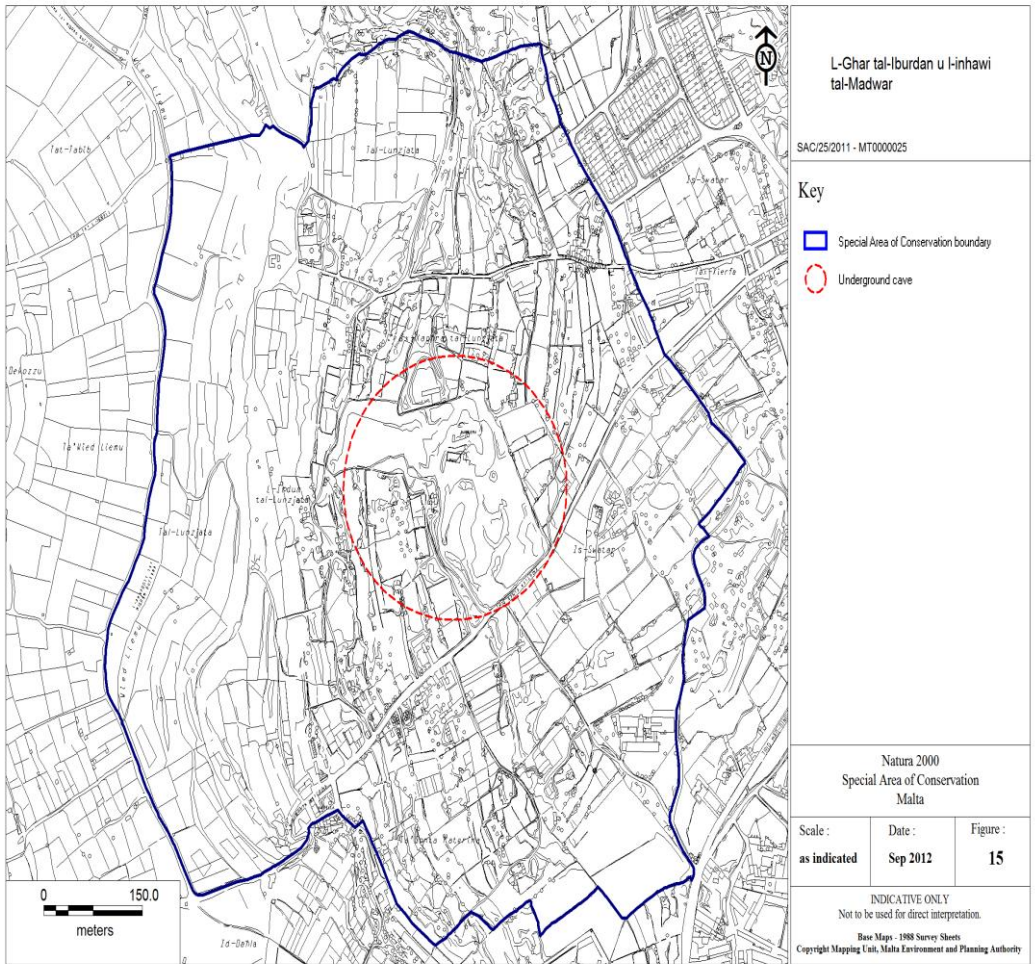


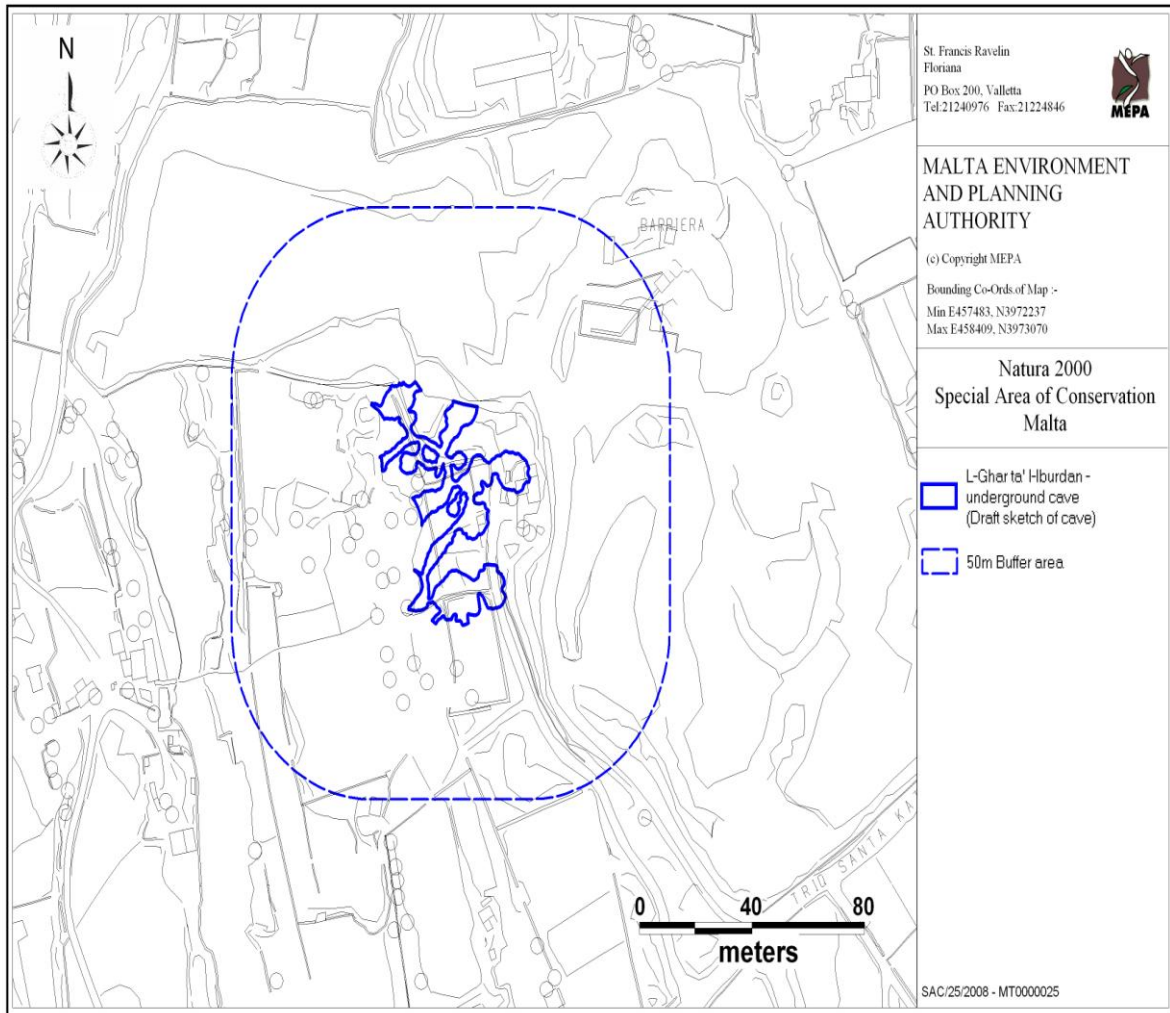


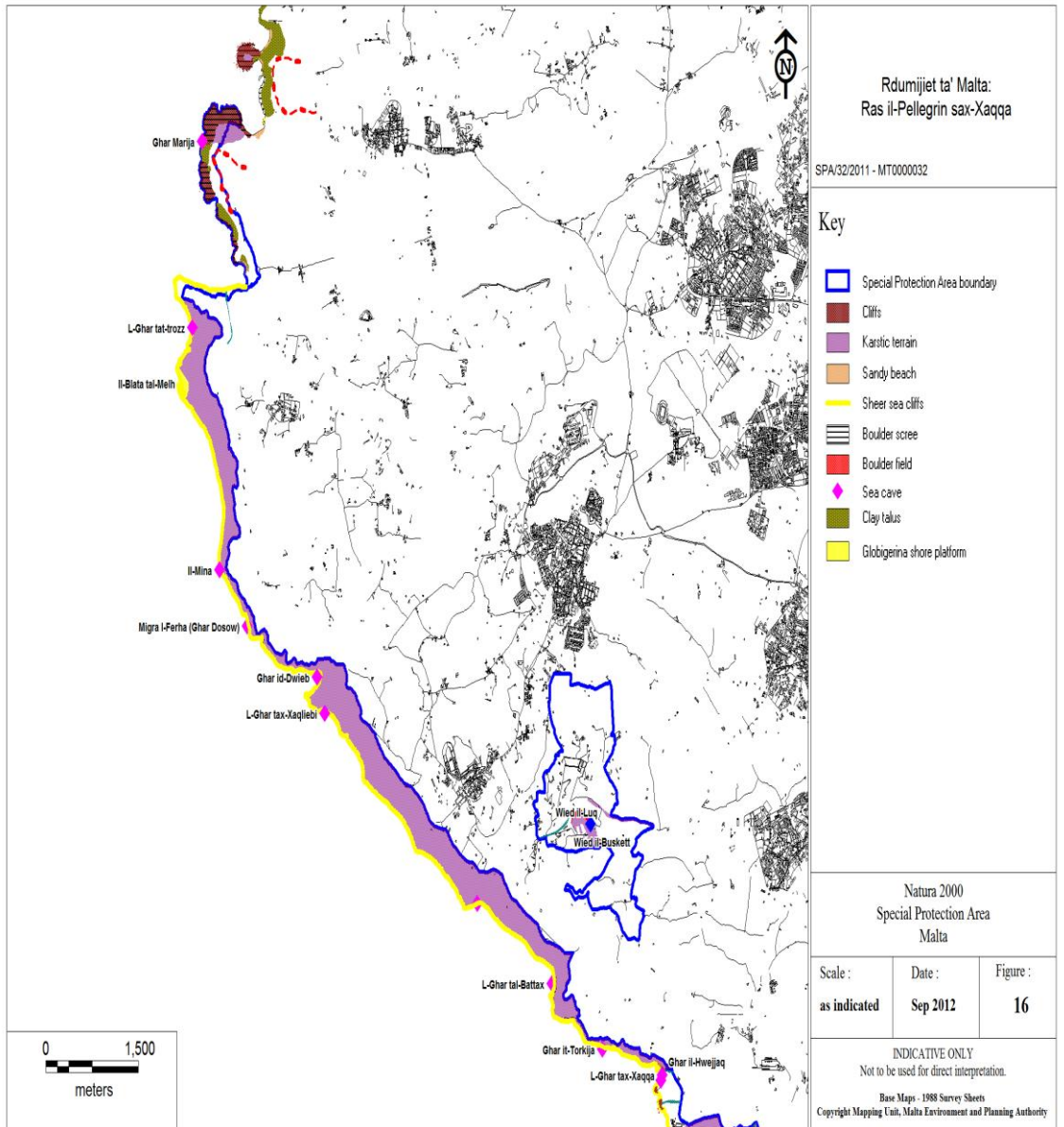


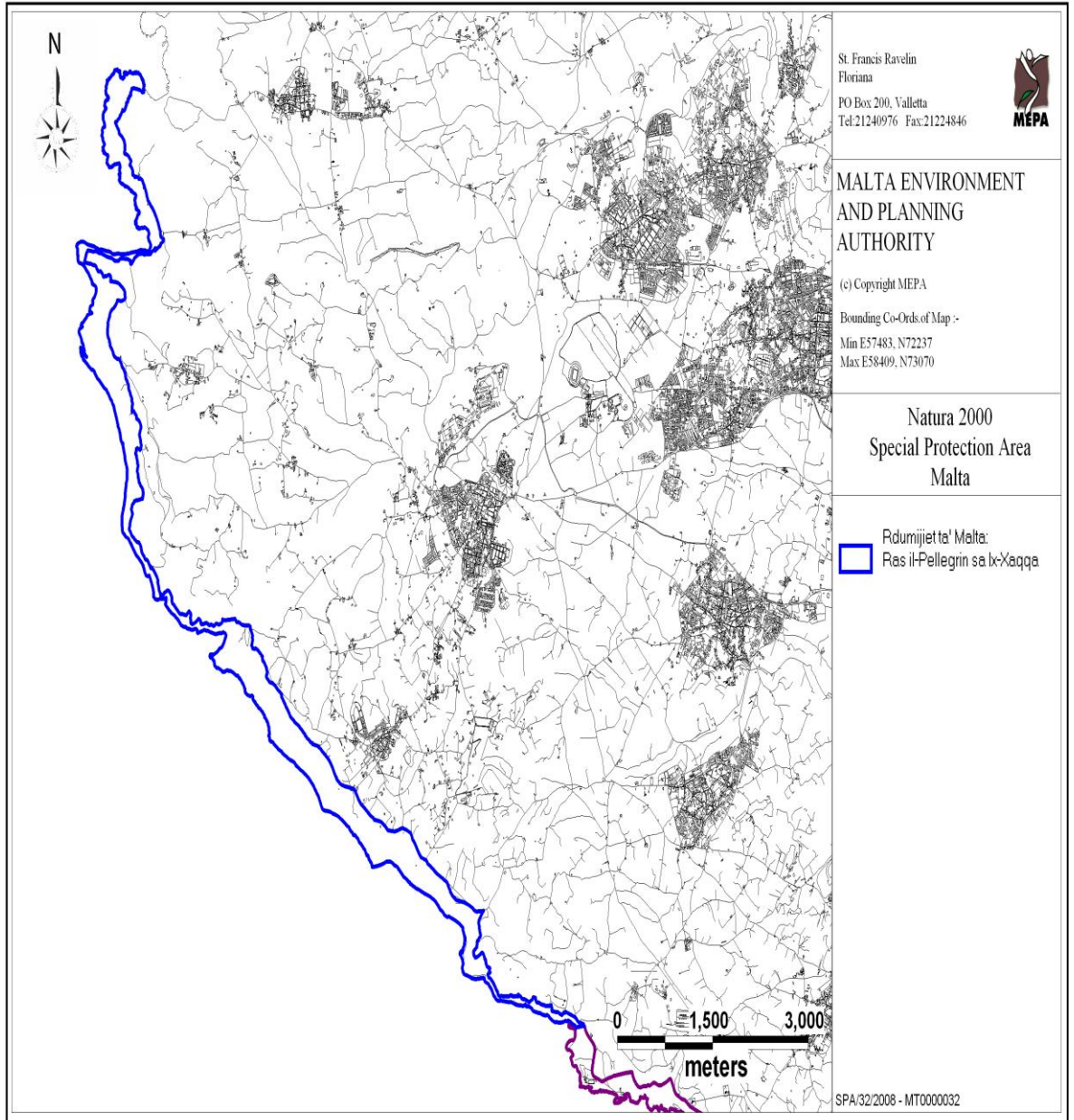


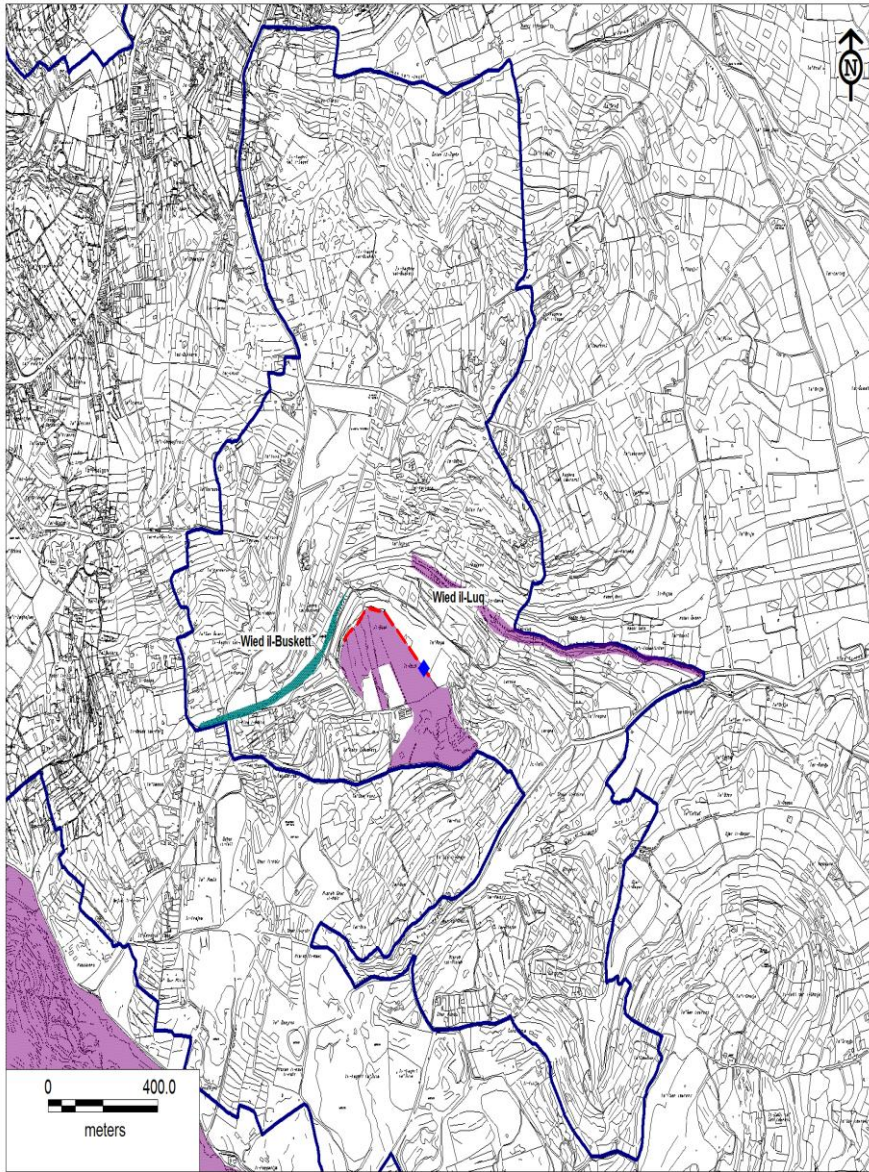












Buskett & Girgenti areas

SAC/18/2011 - MT0000018

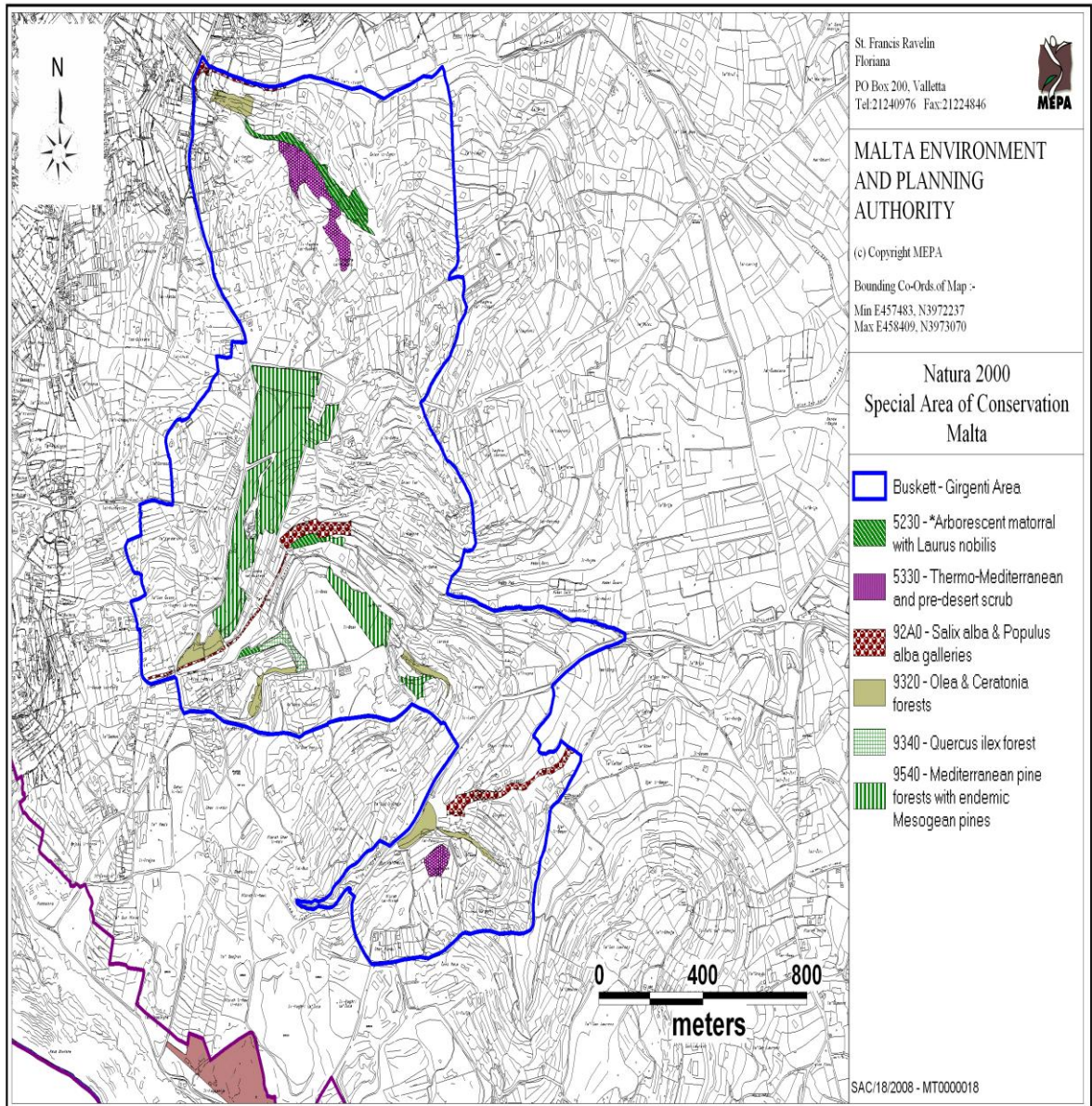
Key

- Special Area of Conservation boundary
- Karstic terrain
- Valley system
- ◆ Karstic cave (with vertical mouth)
- Escarpment

Natura 2000
Special Area of Conservation
Malta

Scale :	Date :	Figure :
as indicated	Sep 2012	17

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**MALTA ENVIRONMENT
 AND PLANNING
 AUTHORITY**

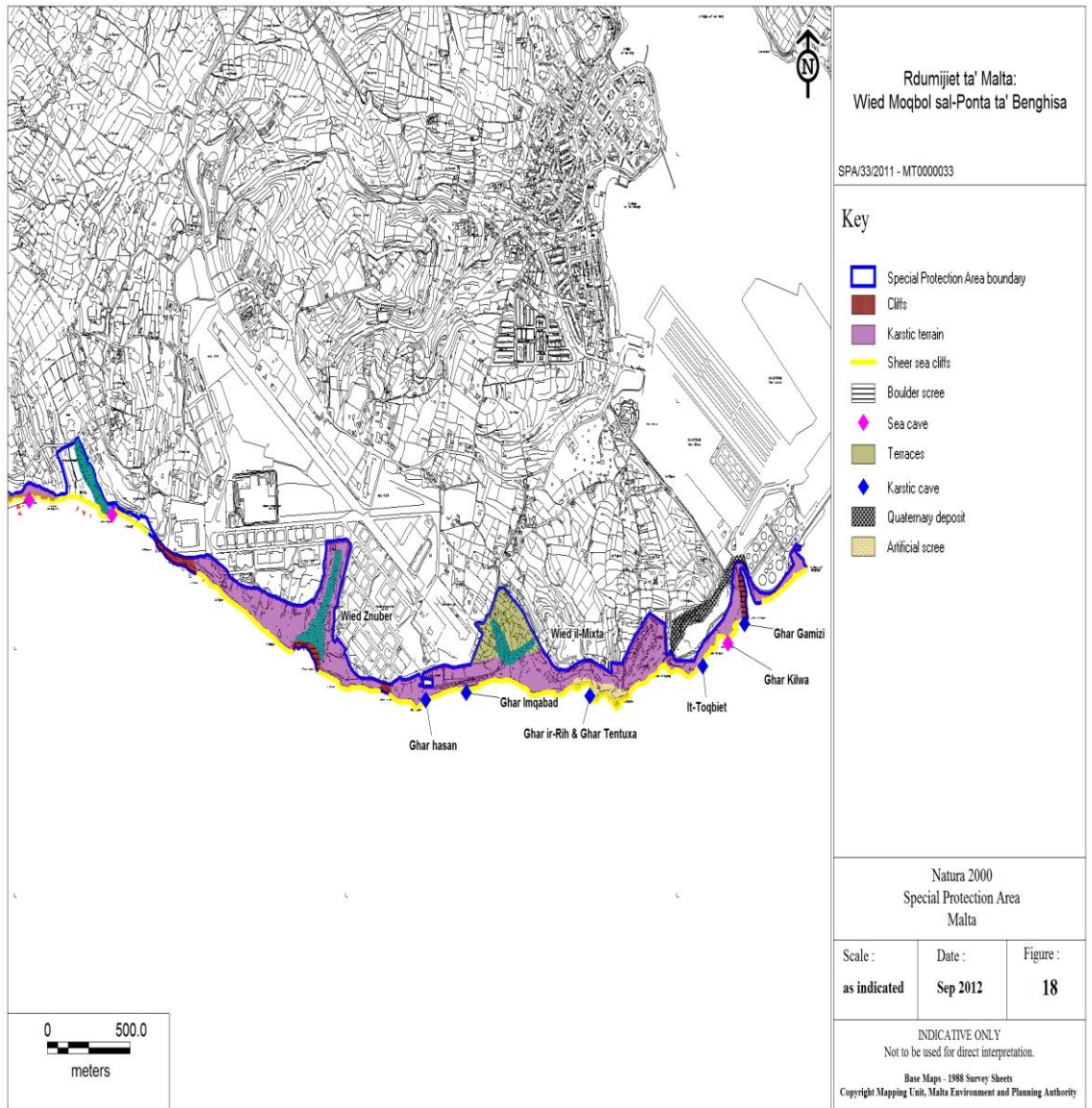
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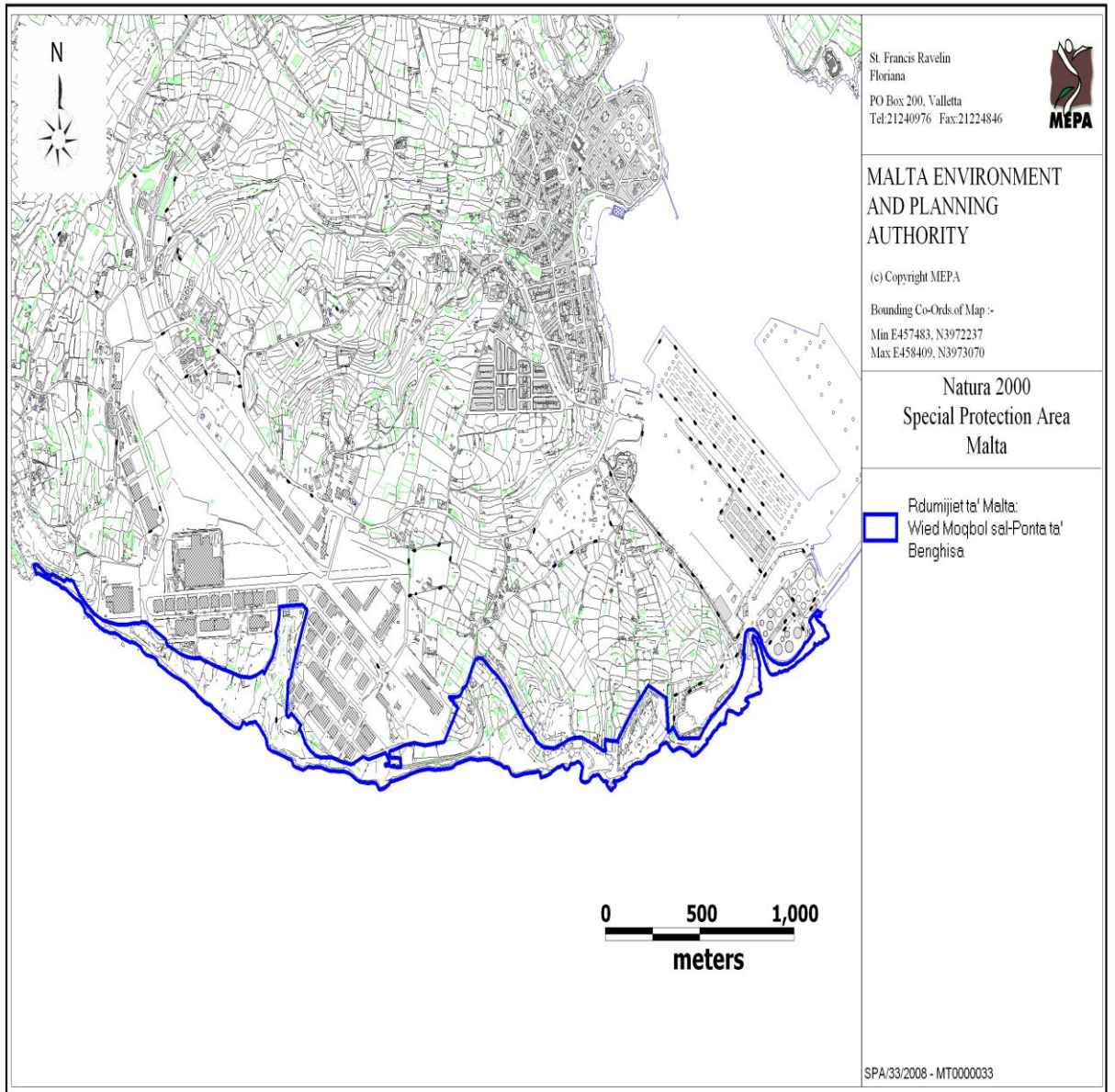
Bounding Co-Ord. of Map :-
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 Max E:458409, N:3973070

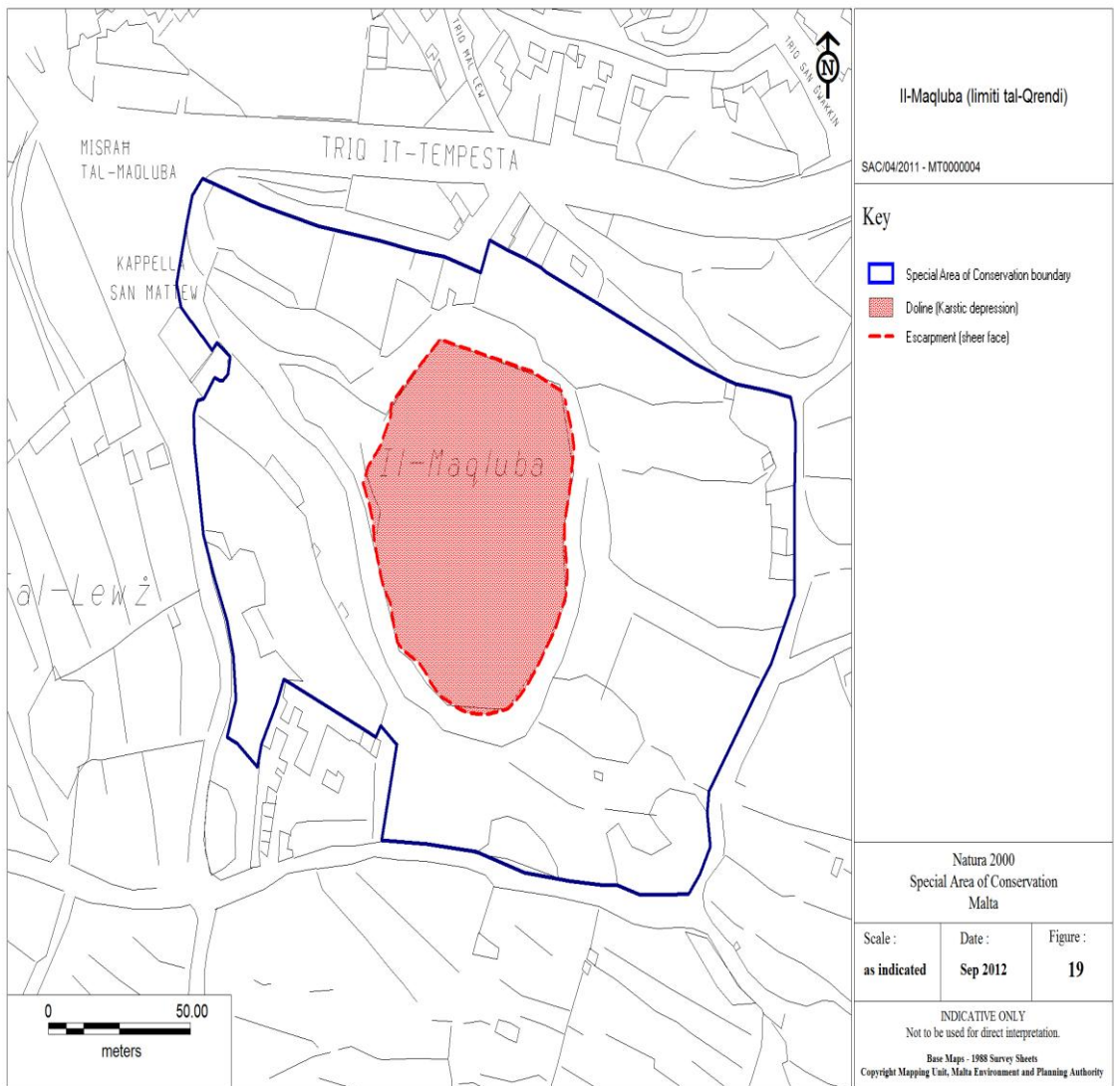
**Natura 2000
 Special Area of Conservation
 Malta**

- Buskett - Girdgħa Area
- 5230 - *Arborescent matorral with *Laurus nobilis*
- 5330 - Thermo-Mediterranean and pre-desert scrub
- 92A0 - *Salix alba* & *Populus alba* galleries
- 9320 - *Olea* & *Ceratonia* forests
- 9340 - *Quercus ilex* forest
- 9540 - Mediterranean pine forests with endemic Mesogean pines

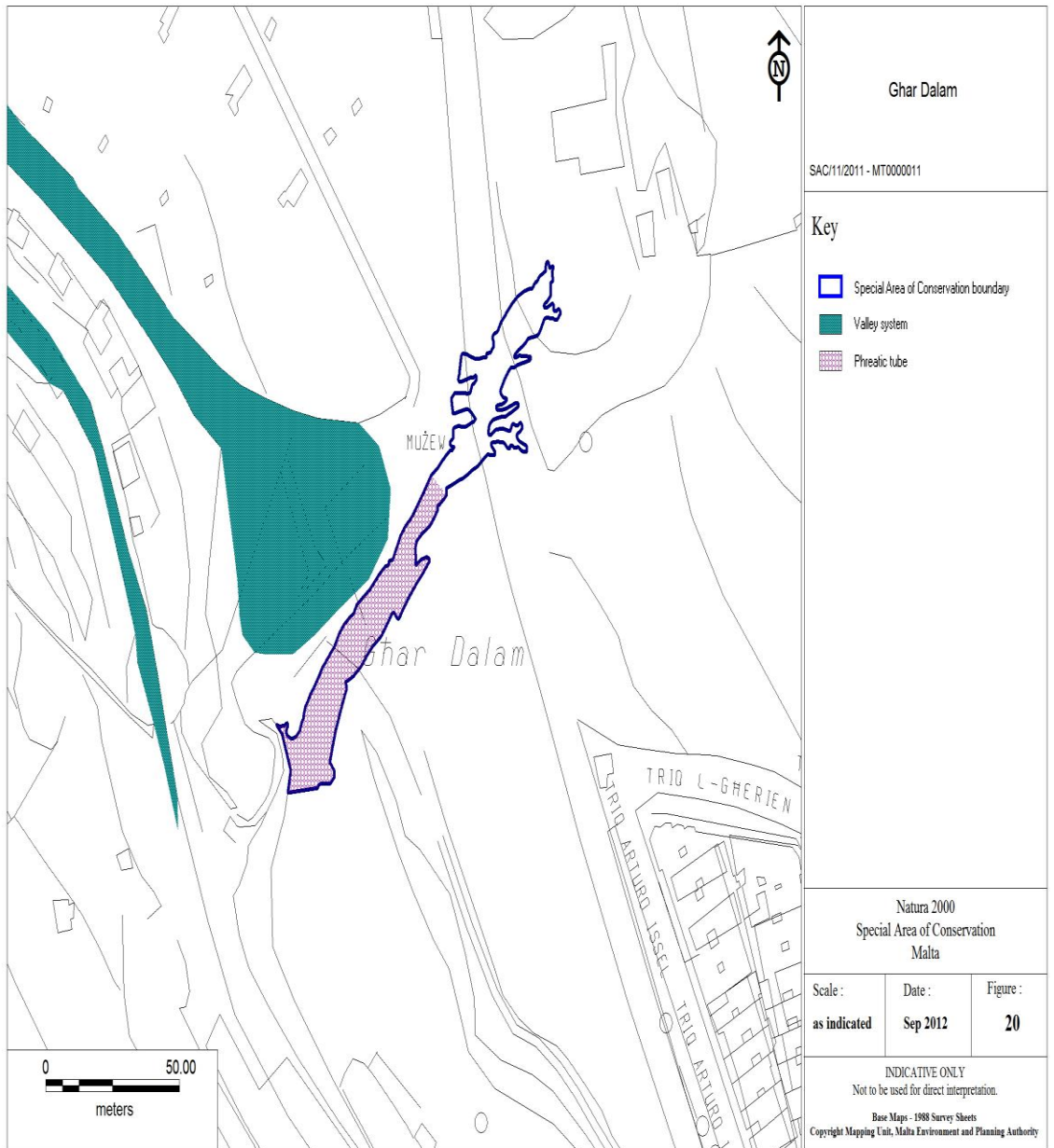
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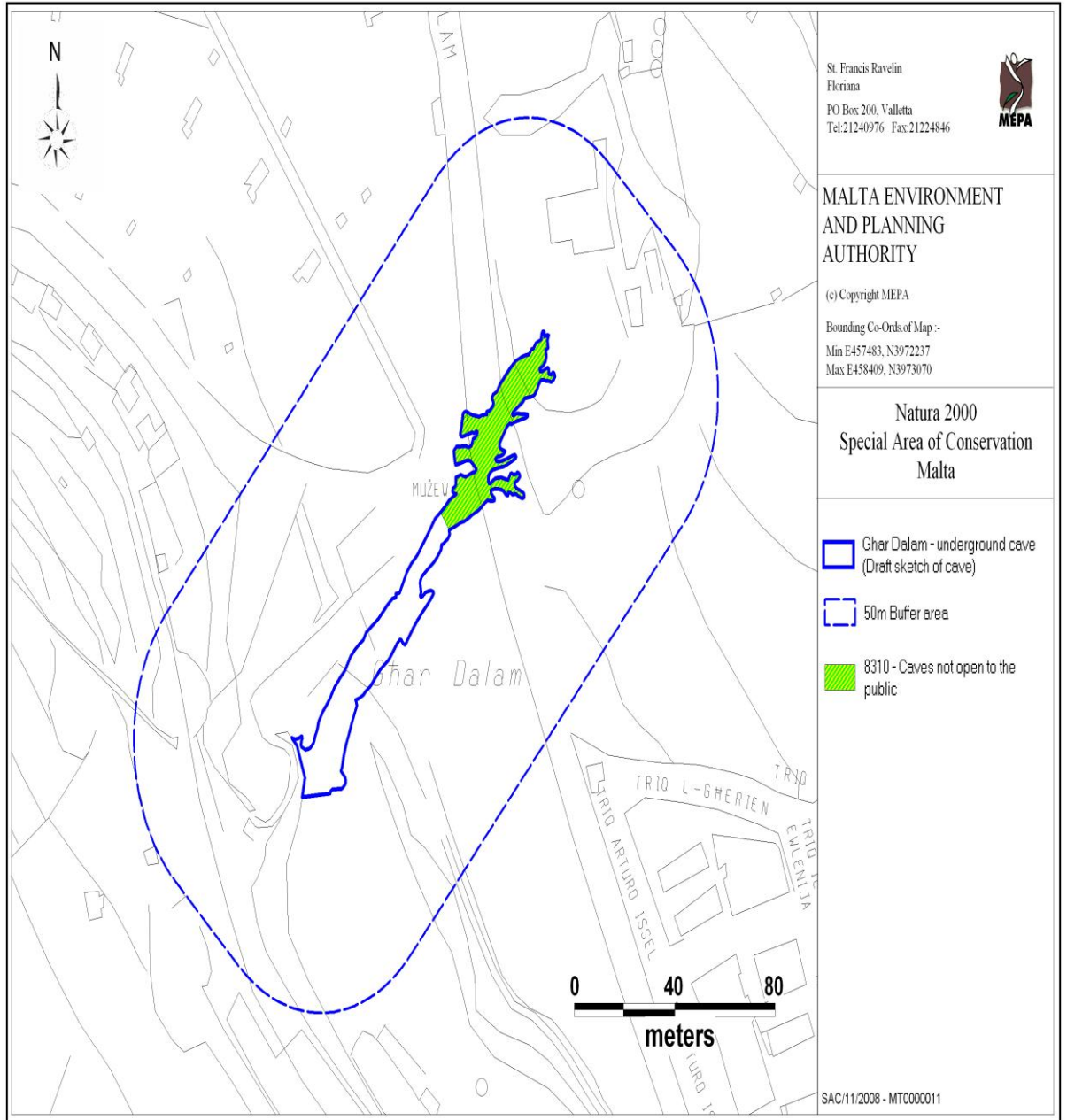


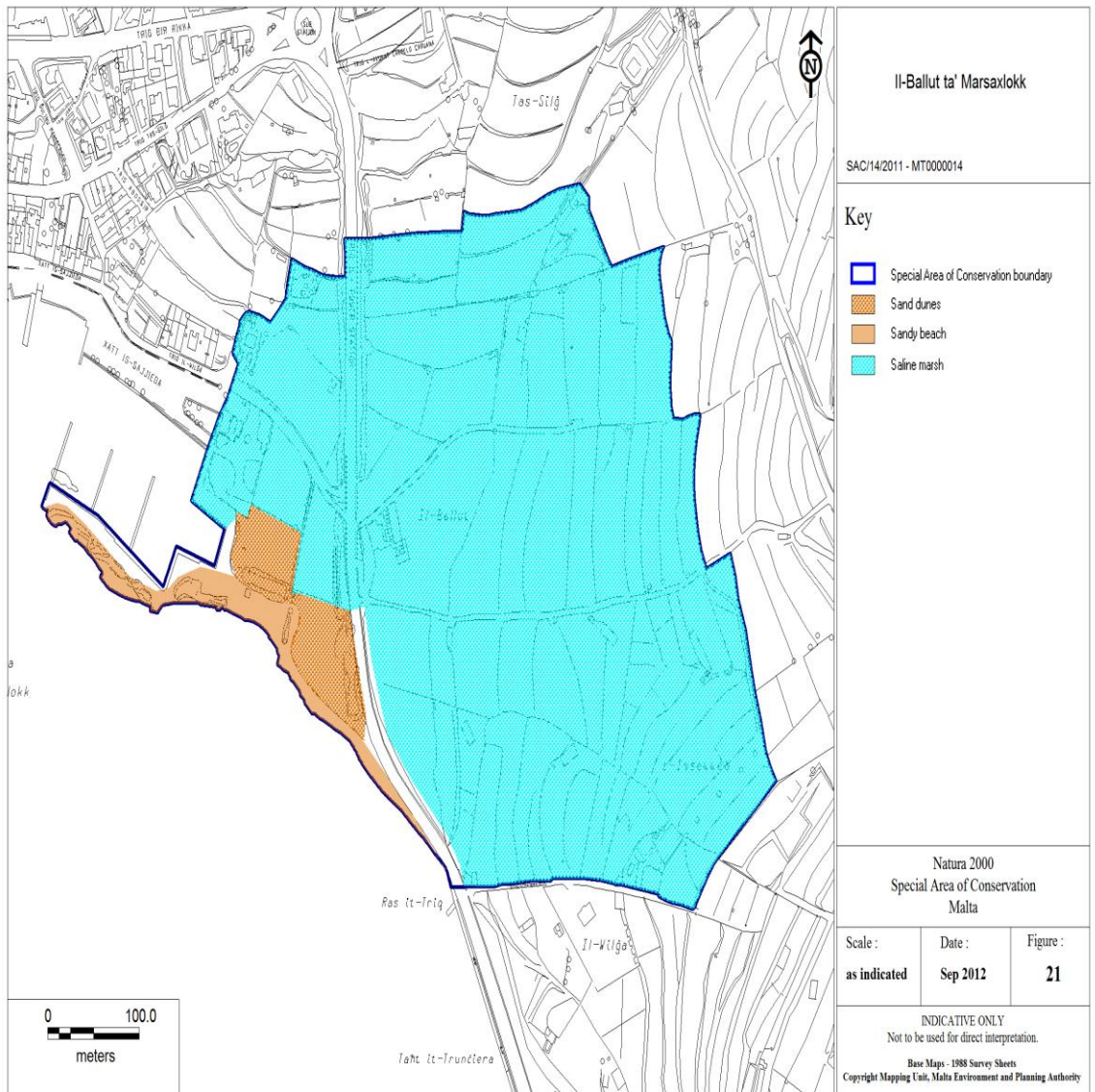


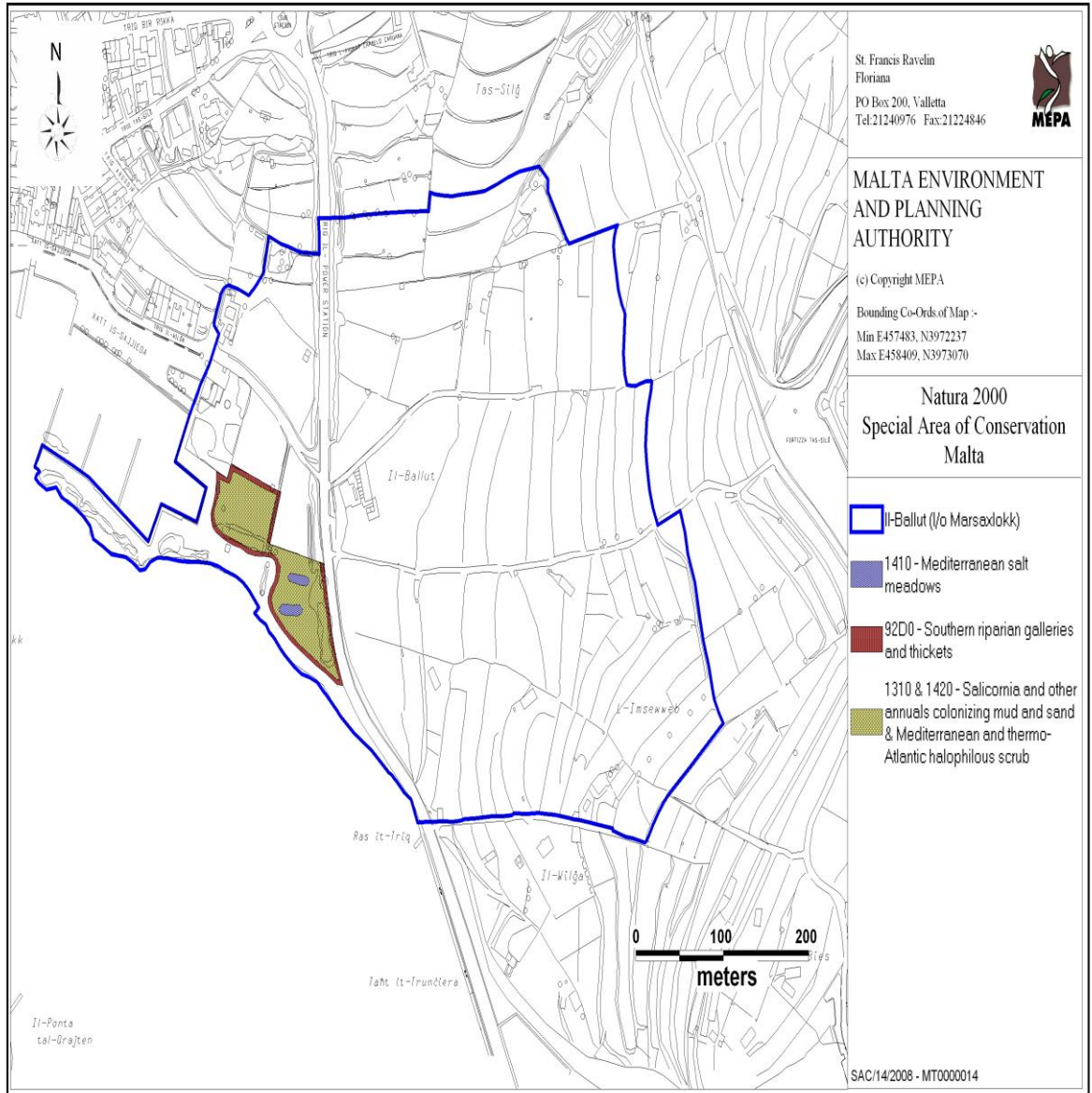












Chapter 6
Conclusions
&
Recommendations

Chapter 6

Conclusions and Recommendations

6.0. Conclusion

The results of this study have proven that the geomorphology of each sited habitat is the main determining factor contributing to what each protected ecosystem has to offer. Hence the unique flora or fauna occur in these sites can only be preserved on a long term basis if the geomorphology is protected to maintain its determining, dynamic and evolving influence. If our landforms, waterways, and soils are left to become degraded, then these will have a profound negative impact on the plants and animals living on or in them.

To make proper pro-active decisions about biodiversity we need to understand where species occur, the habitats they live in and the ecological processes that drive these habitats and larger groupings of communities. Optimum management of geoconservation brings about the promotion of geodiversity and geoconservation, thus making the sites sustainable. Poorly devised and implemented management practises may lead to the destruction of unique geological and biological features aggravated by surface and groundwater pollution. Typical examples are a karstic cave system ongoing land forming processes: this can easily be degraded by inappropriate disturbances in its water catchment area. Disturbance of sand dunes covered by a thin stabilising soil layer by vegetation clearing, fires or vehicle use is followed by old vegetated dunes being “blown out” as a result of deflation. Geoconservation often deals with relict features in which degradation is permanent and unsustainable as these are not still forming. Therefore, unlike bioconservation where things can be potentially ‘re-grown’ through restoration ecology, geoconservation management of such features should be more active.

Since geodiversity provides all the environmental factors which directly influence biodiversity, geoconservation is an essential part of bioconservation. Geoconservation retains physical abiotic features of interest. For example, it maintains a clear exposure of a stratigraphical sequence in an eroding cliff (despite

erosion) by interacting with natural change. Therefore, unlike preservation, it does not stop erosion. Preservation on the other hand, assumes that the item being afforded protection is not changing, since the notion of preservation maintains, unchanged, the asset that is being protected. Since landform changes due to its dynamic nature, it is best to resort to conservation approaches which recognise that landforms are in a constant state of flux. Geoconservation enhances and conserves geological and geomorphological features, processes, sites and specimens (Burek & Prosser, 2008).

The performance of an evaluation process will help to assign a geomorphological value to all sites (Zouros, 2005). This process can be based on 1) Their scientific and educational value; 2) natural beauty and aesthetic value; 3) cultural interest; 4) geodiversity; 5) potential threats and protection needs; and 6) their potential for human use based on the geographical distribution, accessibility and potential for generating economic activities (*ibid*).

However, successful conservation often depends on understanding and valuing the feature, process, site, or specimens to be conserved (Burek & Prosser, 2008). Therefore the actions taken should include promotional awareness raising activities related to geological, geomorphological features, processes, sites and specimens. Such activities would initially include awareness, examination and scientific audit exercises. Actual appraisal and awareness of perceived threats to the public will accelerate interaction by every strata of the local society. Examples of such activities include the appreciation that geomorphological features, processes, sites and specimens do exist, as well as specimen collecting for curiosity, mapping of geomorphology, visiting and describing features and sites highlighting the concern and desire to act (Burek & Prosser, 2008). These activities foster awareness of natural environment or heritage by acting as a catalyst to the subconscious state. This will immediately help the authorities to take positive action to counteract any threats to the conservation of these sites.

On the other hand, action to identify conservation priorities can be done through a conservation audit which would help to prioritise the threatening factors. Geoconservation has to be protected by a national legal framework. The creation of

geoparks will help to promote, protect and rationally manage the related geosites by exposing the public’s pride to their national geomorphological heritage.

“the potential of geoparks is to be used as a basis for enhancing the promotion of geological heritage in order to educate the public at large in geological sciences and in environmental matters; ensure sustainable development (geotourism); and protect endangered geological heritage sites for future generations” (UNESCO, 2004).

Management is another example of direct action. By proper management one is protecting these important sites. This would involve purchasing the land or specimen, followed by the creation of a reserve and securing the conservation of the site. Proper scrutinised exposure to the public will enhance the protection of all related sites. Management of individual geomorphological sites should be based upon the knowledge of the scientific and educational value of these sites, an understanding of the potential threats being both natural and anthropogenic, monitoring of the sites where necessary. If a site has deteriorated the need of direct management to restore and reverse it to a better status (JNCC, 2012) has to be implemented immediately.

Indirect action helps awareness and raises the importance of geoconservation through the media, books, and interpretation, lobbying of politicians, education and the involvement of the local community. Geoconservation has to be professionally managed as part of a strategic, holistic and integrated approach to managing the natural world, with the interdependence of all aspects of nature.

Activity relating to geomorphological features, sites and specimens	Examples of activity	Comments
Initial awareness	Appreciation that these feature, sites and specimens exist	Not geoconservation: Awareness of natural environment
Examination, description, scientific audit	Specimen collecting for curiosity, visiting and describing features and sites and mapping	Not geoconservation: collecting and scientific description
Value/ appreciation	Retaining specimens and telling	Not geoconservation:

	others about features/sites	Subconscious state likely to result in support of conservation if threat is perceived
Awareness of threat	Concern and desire to act	Not geoconservation: Likely to be followed by geoconservation
Unintended or coincidental activity leading to geoconservation	Conservation of a valued woodland, including a geological feature that coincidentally benefits from conservation of the woodland	
Conservation audit	An assessment of what is important to keep and where it is	Geoconservation: action to identifying conservation priorities
Protection through legal/policy means	Conservation legislation or National Park/planning policy	Geoconservation: action to protect through law or practice
Management	Purchase of land or specimen, creation of reserve, securing of a site, enhancement of an exposure	Geoconservation: direct action to protect or manage
Awareness raising of importance of feature	Books, media, lobbying of politicians, education, involvement of local community	Geoconservation: indirect action to build support for conservation
Development of a holistic approach to conservation showing the interdependence of all aspects of nature	Integrated landscape scale approaches, integrated biodiversity/geodiversity/landscape	Geoconservation: as part of a strategic, holistic and integrated approach to managing the natural environment

Table 6.1: A summary of efficient geoconservation measures towards this study. Source: (Burek & Prosser, 2008) and edited by author.

Benefits to geoconservation can be enormous if the site-based approach is complemented by a natural area/wider landscape approach. This is through the

protection of topographical character, restoration of geomorphological processes and the creation of new exposures in important geological units. Site and selection assessment serves to provide a framework around which to build a proper geomorphological conservation program. By assessing a bioregion, patterns in the landscape can be linked to flora and fauna assemblages. Also evolving processes at the ecosystem scale can be intensively investigated to provide a useful means for simplifying and reporting on more complex patterns of biodiversity. These areas a relatively large land areas characterised by broad, landscape-scale natural features and the functions of entire ecosystems are influenced by environmental processes. An ecoregion which is smaller than a bioregion (UNESCO, 2012) can be used as a unit of analysis as a conservation measure.

Therefore one can conclude that strong legislation, conservation-friendly policies, practice and action plans, an active geological/conservation community, and activities aimed at raising awareness of the importance of our geomorphological heritage and the need to conserve it, amongst both decision makers and the public are all the keys to achieving truly successful geoconservation.

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