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Understanding marine ecosystem services in Malta: A focus on climate regulation, nursery habitat and recreational services

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Understanding Marine Ecosystem Services in Malta: A Focus on Climate Regulation, Nursery Habitat and Recreational Services

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Acronyms

CCN – Cloud Condensation Nuclei
DMS – Dimethylsulfide
EEZ – Exclusice Economic Zone, 25 nautical miles off of Malta's coast
FMZ – Fisheries Management Zone
GHG – Greenhouse gasses
IPCC – Intergovernmental Panel on Climate Change
MA - Millennium Ecosystem Assessment
MEPA – Malta Environment and Planning Authority
MPA – Marine Protected Area
TBT - Tributyltin
WTO – United Nations World Tourism Organization

Glossary of selected terms

A1B Scenario – IPCC Scenario for modeling. It is based on conditions of rapid economic growth, increasing population that peaks mid century and declines thereafter, and rapid development and implementation of technologies based on a balance between fossil intensive and non fossil fuels.
Benthic – The zone comprising of the bottom of the sea or other body of water.
Bunkering – The process of supplying a ship with fuel offshore.
Demersal – The part of the water column closest to the bottom.
Insolation – The amount of solar radiation that a given area receives.
Neritic – A nearshore coastal zone, also referred to as inshore or on the continental shelf.
Oceanic – Ocean zone considered off of the continental shelf.
Pelagic – Within the water column.
Recruitment – When juveniles become adults, signaled by movement to adult habitat or entrance into a commercial fishery.
Settlement – When larvae become juveniles, often signaled by a change in habitat.
Turbidity – A measure of the degree to which water has lost its transparency.

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Abstract

The research explored the relationship that people have with marine environments around Malta through the framework of ecosystem services with the idea that the results of this research could be used as a starting point for the development of a management plan for the marine environment around Malta. Surveys were conducted targeting residents, tourists, and divers to gain an understanding of stakeholder perception of the threats facing climate regulation, provision of nursery habitat and recreation. These data were used to develop a GIS where essential areas and impacts were compared and areas of potential conflict were identified. There were significant numbers of areas of overlap between impacts and essential habitat that were identified. It is likely that these areas of overlap will result in conflict or loss of service in the future. Community based marine spatial planning may be a way to prevent conflict and degradation. Results from the surveys indicated that community involvement in management might be hampered by a lack of comprehension of the complex processes and vocabulary, though stakeholders appear to be well versed with the associated pressures and impacts.

1. Introduction:

This research explores the relationship that people have with marine environments around Malta through the framework of ecosystem services. Ecosystem services are the free goods and services that nature provides to people (Millennium Ecosystem Assessment, 2005). The idea that nature gives people goods, services, and benefits is not a new concept: however, it has had a resurgence and greater emphasis placed on it since the publishing of the Millennium Ecosystem Assessment (MA) by the UN in 2005. As the MA reports

> *"Everyone in the world depends on nature and ecosystem services to provide the conditions for a decent, healthy, and secure life."* Summary pg 5
>
> (Millennium Ecosystem Assessment, 2005)

Humans are constantly changing ecosystems to enhance one ecosystem service at the expense of others. Terrestrial forests are being cut down for agriculture and other ecosystems are altered to obtain, coal, oil, fresh water, fish and shelter. The consequences of these ecosystem changes are declines in other services that the ecosystems, in their previous state, provided. The continuation of these services is essential to the survival of humans around the world.

As a small island nation, Malta has few natural resources on land (Stevens, Lanfranco, Mallia, & Schembri, 1995). This makes it essential for Malta to protect the goods and services provided by the marine habitats surrounding the island. This also means that Malta uses the marine area for a large number of activities that may have an impact on those same marine environments. To evaluate these ecosystems, the European Environment Agency recommends using a DPSIR framework of evaluation (Kristensen, 2004).

The DPSIR framework was designed as a way to give policy makers information about environmental quality and the effects of specific policy responses (Kristensen, 2004). DPSIR stands for Drivers, Pressures, State, Impacts, Response. Each element within this group is

considered to link with the others such that Drivers cause Pressures, which influences the State, which Impacts the ecosystems, which causes policy makers to decide on some kind of Response. Responses can be made at any of the categories to influence the system. A diagram of this idea is shown below in Figure 1. Drivers are needs that a group has (Kristensen, 2004). People have the need for food, water and shelter, a country has a need for a growing GDP or low unemployment, an industry might need raw materials or to make a profit. Policy solutions here might mediate disagreements where one group's needs clash with another group's needs, or where the idea of wants versus needs becomes an issue.

Pressures are the result of human actions to try to fulfill the needs of Drivers. These actions stress the environment through three ways: i) excessive use of resources, ii) changes in land use or iii) emissions of pollutants (Kristensen, 2004). Each of these behaviors alters the condition or State of the environment. Ultimately, changes in the State of the environment alter the ability of ecosystems to survive and to provide humans with goods and services. This may cause Impacts to human health, economics, the environment, or human welfare in general

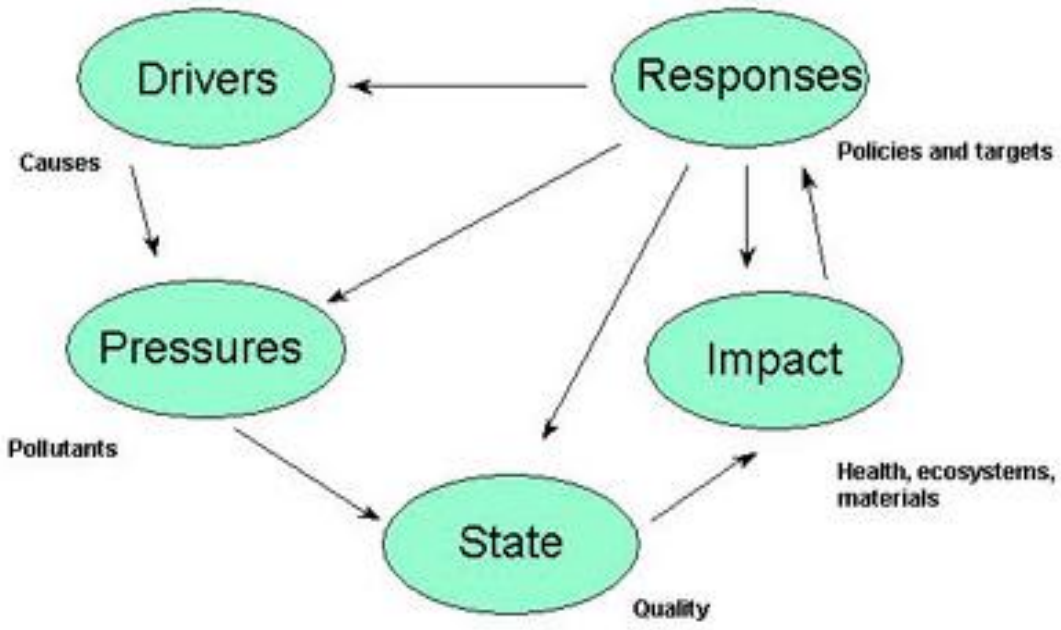


Figure 1: The DPSIR framework from {{223 Kristensen, Peter 2004}}

(Kristensen, 2004). When undesired Impacts occur, governments and society can implement Responses to try to prevent this undesired Impact. These Responses in turn affect the different DPSIR Categories.

This research uses a set of surveys of resident, tourist, and diver groups to identify the Pressures affecting three different marine ecosystem services: Climate Regulation, Nursery Habitat, and Recreation and Tourism. The identification of pressures by the surveys and through other means of research was then combined with a Geographical Information System (GIS) to present maps showing the State of these ecosystem services. Efforts were made to combine the locations of the Pressures with the locations of ecosystems providing these ecosystem services. These data would facilitate the discussion of whether policy responses were needed and what they should be. The goal of the GIS section is to identify what the situation is in 2011. This will provide a starting point for policy makers, managers, scientists, and the public to develop an idea of what they would like the situation to be in the future and create policies that will facilitate this.

The MA emphasizes the idea that policy responses to protect ecosystem services need to involve local stakeholders throughout every step of the process to elicit successful results (Millennium Ecosystem Assessment, 2005). Environmental policy is often dominated by scientific and political 'experts' because of the complex nature and the often secondary perception of the issues involved. To guarantee the involvement of all stakeholders, it is important to structure the public debate in terms that all stakeholders can understand. In this vein, the surveys were designed to examine stakeholders' knowledge of the three ecosystem services, pressures and some of the terms associated with them. This information should help to frame the public debate about marine ecosystem services; if they should be protected, as well as how and where limited funds and resources can best be utilized.

The ecosystem services concept is a useful tool for identifying and at times quantifying the value of specific services and ecosystems. People make decisions everyday about where and how to use their limited resources. Their time, money, skills, and private goods are compared to their needs, wants, benefits and costs and allocated according to their own personal value system. On a larger scale, governments do this to manage public goods like national defense or clean air as well as common pool resources such as fish in the ocean or the water in an aquifer. When there is uncertainty about the needs, wants, benefits and costs of how resources should be allocated, resources may be used in ways that are harmful to the country and the ability of the environment to produce future resources. The ecosystem services concept was introduced as a way to better inform decision makers about the benefits and costs associated with a particular habitat and how their actions could affect the ability of the environment to continue to provide these services. The last goal of the surveys was to identify the value that people place on the different ecosystem services addressed in this research.

The results of this thesis should provide policy makers, managers, and scientists a starting point for a debate over the fate of the marine ecosystems around Malta. While only three ecosystem services (climate regulation, nursery habitat, and recreation and tourism) were examined, the important habitats for these services are the same habitats required for many other services. By ignoring these ecosystems, the services they provide and future plans for these areas, Malta risks destroying these ecosystems through inaction. Without assigning value to its ecosystems and determining the range of acceptable human impacts upon them, Malta leaves these systems to the chaos of unplanned expansion that is likely to destroy an already tenuous balance between mankind and the environment.

2. Ecosystem Services:

2.1 The Ecosystem Service Concept:

The term "ecosystem services" is not well defined. There seems to be a general understanding of the term throughout the science world, but each researcher defines it quite differently in the course of his or her work. Colloquially, ecosystem services are things that nature provides to humans (Fisher, Turner, & Morling, 2009). This broad and simplistic definition conveys the idea that humans depend on the environment, but does not give an indication of how or why this is important. The multiple definitions of the term confuse policy makers and the public, making it difficult to use research to define policy (Boyd & Banzahf, 2007). Without a clear definition of what is meant by "ecosystem services," it is difficult to make meaningful comparisons across projects and between disciplines (Fisher et al., 2009). A clear definition with well-established boundaries allows for pattern recognition and discovery of the essential links between humans and the environment (Fisher et al., 2009).

Westman (1977) was one of the first to discuss the idea that there can be non-monetary value in the products brought forth by nature. Westman divided 'nature's services' into goods (the structure of an ecosystem including the quantity and arrangement of species in an area) and services (the ways that the components of an ecosystem interact) (Westman, 1977). Since then, there has been further work to identify and create an assessment and monetary valuation of the services provided to humans by nature. A big step for the valuation of ecosystem services was the Millennium Ecosystem Assessment (MA) undertaken by the United Nations in 2005. The MA defines an ecosystem service as "benefits people obtain from ecosystems (Millennium Ecosystem Assessment, 2005)." While similar to the colloquial definition, the MA further refines the definition by categorizing services as supporting, provisioning, regulating, or cultural services. Provisioning services are defined as the products humans obtain directly from ecosystems such as food, water, and fuel. These are the things people think about when asked about what nature provides. Regulating services are those benefits obtained from the regulation

of ecosystem processes. Cultural services are the non-material benefits people obtain from ecosystems. Supporting services are the hidden services that are necessary for the production of all of the other ecosystem services (Millennium Ecosystem Assessment, 2005). While the categories are useful, the definitions of each of the categories lead to some confusion over the category to which a service should belong. For example, recreational activities can result in direct profits, a material benefit, but the value of recreation is in the feelings one gets from being in a natural environment, a non-material benefit. This definitional problem can lead to what economists call double counting (Boyd & Banzahf, 2007; Fisher et al., 2009).

Other definitions have been developed by leading authors on the subject. Many stick with the definition set forth in the MA including Naidoo and Daily (Daily & Matson, 2008; Naidoo et al., 2008). Costanza *et al* take the definition a step further, defining ecosystem services as *"the services and natural capital stocks provided by ecological systems that are critical to Earth's life support systems* (1997)." This definition does not directly mention a human aspect, allowing the services to be of worth on their own, though clearly people are part of life on earth and depend entirely on these systems. The authors break down their own definition further by explaining that natural stock combines with manufactured and human stock to increase human welfare. Thus, the definition Costanza *et al* offer requires natural as well as human processes to produce human benefits (Costanza et al., 1997). This eliminates services like maintenance of genetic or biological diversity. However, Costanza does mention that these services and stocks can contribute either directly or indirectly to human welfare (Costanza et al., 1997)in contrast with Boyd and Banzahf who only count the direct consumption by people as benefits (Boyd & Banzahf, 2007).

The definition given by Boyd and Banzahf is *"the final ecosystem services that are components of nature, directly enjoyed, consumed or used to yield human well being."* (2007 pg 619)

They intentionally choose to dismiss immediate products, assuming that these products and processes are included in the final valuation, to avoid the problem of double counting (Boyd & Banzahf, 2007). The problem is that the final costs of a good often do not consider intermediate costs. By neglecting to take intermediate processes into account, countries all over the world increased degradation of ecosystem services over the last 50 years. For example, when the benefit of a fruit is examined, the processes that provided the clean water, nutrient rich soil, and pollination services are ignored because it is assumed that these services are taken into account when valuing the fruit. For their goal of creating an "ecological unit" of valuation, this makes sense. However, if these ecological units are going to be useful for decision-making, it is important that the ecological unit value for final products does actually include the ecological cost of the intermediate steps and that it is not directly tied to monetary valuation. One large distinction that Boyd and Banzahf make is the difference between a service and a benefit. Benefits require human and social capital to produce advantages from the services that ecosystems provide (Boyd & Banzahf, 2007). Using recreation as an example, the ecosystem provides the fish, invertebrates and aesthetic quality of a coral reef, but scuba tanks or snorkels are required for people to gain the benefit from the services.

Several authors have attempted to provide a 'monetary valuation' of the services a particular ecosystem provides. These environmental valuations can provide support for decisions to protect ecosystems by allowing a quantitative comparison between costs and benefits (Christie, Hanley, Murphy, Wright, & Hyde, 2006). These valuation systems seek to override the public's lack of understanding of complex environmental processes by putting these processes into a 'common currency.' As ecosystem services are often poorly understood, they are not captured in market economics and as such, they are undervalued in policymaking (Boyd & Banzahf, 2007; Costanza et al., 1997; Daily et al., 2009; Fisher et al., 2009; Westman, 1977). The goal then is not to determine the monetary amount of nature's *total capital*, as without

ecosystems the earth would be uninhabitable and therefore the total value is indeed priceless, but rather to be able to meaningfully compare the costs that will occur due to changes to ecosystems if a specific policy is instituted (Freeman, 2010). Papers such as that by Costanza *et al* (1997) and the MA (2005) miss this point because they are focused on large-scale results and global or entire ecosystem-based determinations of value. On such a large scale however, the value of a loss of even just one service or ecosystem is truly an incalculable number. The question then becomes how localized decisions can reflect both the global and local impact of the ecosystem to function productively.

The oceans themselves present a very difficult group of ecosystems with which to assign a value. The high degree of connectivity, large size (71% of the earth's surface, but 99% of the earth's living space) and the difficulty of both accessing and restricting access make the components of these ecosystems more complex and less understood than their terrestrial counterparts (Costanza, 1999). Of the different ecosystems on the earth, coastal ecosystems are perhaps the most valuable to human well-being. Though these systems only account for 6.3% of the earth's surface area, they are responsible for producing 43% of the calculated value of the world's ecosystems (Costanza, 1999). In fact, the value provided by Costanza in a 1999 study estimated the value of ocean ecosystems at 21 trillion dollars annually at a time when global GNP was only 25 trillion dollars (Costanza, 1999).

Functionally, the most difficult part of evaluating ecosystem services is the understanding of how the structure and function of an ecosystem support the service of interest. Many of these linkages are not direct, linear, or predictable, making it more difficult to predict how a system will respond to small-scale changes (Freeman, 2010). Environmental systems are exceptionally resilient, until they reach some unknown tipping point and the effects from actions

are often not felt on the same spatial or temporal scales as policies are designed for (Costanza et al., 1997; Millennium Ecosystem Assessment, 2005).

Using an ecosystem service framework is useful for making policy and management recommendations for a number of reasons. The ecosystem services concept can be utilized by multiple disciplines (Boyd & Banzahf, 2007; Daily et al., 2009; Fisher et al., 2009). Ecologists use the term because it emphasizes the processes in addition to the products that ecosystems provide. Economists find the term helpful because it can assist in the identification of externalities, which once identified can then be incorporated into the cost of products on the market. Policy makers employ the concept to convince the public that conserving ecosystems is in their best interest. The phrase links human well being to environmental health, and it makes the complex relationships between the health of the environment and the health of humans easier to comprehend (Daily & Matson, 2008; Fisher et al., 2009).

According to Fisher *et al*, the ecosystem service classification scheme chosen should depend on the "decision context" for use. (Fisher et al., 2009) As this project focuses on the understanding and appreciation of ecosystem services by the layperson, the classification system of the Millennium Ecosystem Assessment will be used (Millennium Ecosystem Assessment, 2005). The MA uses four easy to understand categories – supporting services, regulating services, cultural services, and provisioning services. While, it has been criticized by Fisher and others for providing a context for double counting as well as for including non-ecological phenomena such as culture, the MA provides a classification scheme that is accessible and emphasizes the human environment link in all aspects of a person's life (Fisher et al., 2009). This project explores three marine ecosystem services important to Malta: (i) the role of the oceans in climate regulation, (ii) the provision of nursery habitat and (iii) recreational use, especially the role of tourism. These specific services were chosen to represent each of the three

lesser known categories, regulating, supporting, and cultural. They were also chosen based upon their importance to the Maltese Islands.

2.2 The Role of the Oceans in Climate Regulation

Climate regulation is an extremely important ecosystem function that can influence a number of services including food production, fresh water provisioning, energy production, disease control, tourism and recreation (Perry, 1997). While weather describes the state of the atmosphere at a particular time and place, descriptions of climate incorporate weather patterns over time, usually decades or more. Annual and seasonal temperatures, precipitation, and wind direction and speed, along with characteristics like latitude, cloudiness, humidity, and length of the growing season are all factors that contribute to a place's climate (Foley, Costa, Delire, Ramankutty, & Snyder, 2003).

Weather is determined by dynamic interactions between the land, atmosphere, and ocean. Complex feedback loops involving the exchange of energy, water and momentum between the systems drive weather patterns (Brown et al., 1989; Foley et al., 2003). Weather is driven by radiation from the sun. As radiation reaches the surface of the earth, it warms the planet. The amount of warming that occurs differs around the planet because of variations in the amount of radiation and materials that absorb it. Some solar radiation reaching earth is reflected back into space, some is absorbed by the various gasses and aerosols in the atmosphere, and some reaches the surface. The components that make up the planet's surface absorb solar radiation in different amounts. Water has a high specific heat capacity, which allows it to absorb and store more energy than the land. Because oceans cover more than 70% of the earth's surface, they have a substantially larger impact on atmospheric conditions than land does (Wainwright & Thornes, 2004). The high specific heat capacity also means that it takes more energy to increase the temperature of water than land, so land heats and cools more quickly

than the oceans (Bernstein et al., 2007). This explains why in the winter, the oceans are warmer than the land, and in summer the land is warmer than the oceans (Brown et al., 1989). During the winter, areas such as Malta that are surrounded by large bodies of water are not as cold as they would be because energy is transferred from the warm water to the cooler air. Both the oceans and continents reemit long wave radiation, but oceans absorb more radiation than they emit, causing them to act as a heat sink (Brown et al., 1989; Hoegh-Guldberg & Bruno, 2010). The ocean absorbs approximately 80% of the energy added to the system via insolation (the solar radiation that reaches the surface of the earth) (Bernstein et al., 2007). Oceans are able to absorb such a large percentage of the incident radiation because they can distribute that energy throughout the entire volume of water (Brown et al., 1989). Within the oceans, energy is gained, lost, and redistributed via currents and mixing processes (Brown et al., 1989). The atmosphere and ocean are constantly exchanging and distributing energy in the process of trying to reach equilibrium.

Along with heat exchange, water exchange is another crucial contributor to weather. The ocean provides the atmosphere with moisture that can affect vertical convection and stability (Brown et al., 1989). It also provides the water vapour that forms clouds and eventually falls as precipitation. One of the reasons that insolation is not evenly distributed between the oceans and continents is that areas covered by oceans have increased water vapour that results in increased cloud formation. The clouds reflect and absorb some of the insolated radiation, so not as much reaches the water's surface, the measure of this reflectivity is called albedo (Brown et al., 1989). Cloud formation occurs when evaporation super-saturates the air with water vapor, causing the warm moist air to rise. Once in the atmosphere, water vapour condenses around aerosol particles called cloud condensation nuclei (CCN) (Andreae & Rosenfeld, 2008). CCN are created from a variety of sources including sulfate, organic particles, and sea spray from the oceans (Andreae & Crutzen, 1997). The largest biogenic source of CCN

is derived from dimethylsulfide (DMS), a substance excreted by phytoplankton (Andreae & Crutzen, 1997; Charlson, Lovelock, Andreae, & Warren, 1987). While scientists believe that DMS plays an important role in regulating clouds and precipitation based on the large proportion of DMS in CCN for remote marine regions, there is still little understanding of the process (Andreae & Rosenfeld, 2008). The cloud formation feedback loop is still the least understood loop affecting climate (Bernstein et al., 2007) and it is unclear how plankton concentrations might affect it. There has not been a consistent correlation between chlorophyll levels (and corresponding phytoplankton levels) and DMS concentrations, a fact that is partially attributed to the diversity of phytoplankton species (Andreae & Crutzen, 1997). This is further complicated by the complex dynamics of the viruses, bacteria, and zooplankton influencing DMS production (Andreae & Crutzen, 1997; Andreae & Rosenfeld, 2008). Despite the lack of understanding of the process, cloud formation and the resulting albedo and precipitation have an effect on reducing solar radiation and increasing freshwater supplies.

The Mediterranean climate is characterized by seasonal variability with hot dry summers and mild wet winters (Perry, 1997). Historically, this meant that summertime was the period for travel and war, while winter was for planting and building, though modern conveniences like irrigation have extended the growing season year round (Perry, 1997). Winter rainfall begins in October when the subtropical jet moves from Turkey to Sudan as a result of the annual contraction of the circumpolar vortex (Perry, 1997). This brings cold air from northern Europe southward where it meets the moist Mediterranean air causing rain (Perry, 1997). The high rates of evaporation in the Mediterranean, even in the winter, ensure that the air remains saturated with water vapour, so that clouds form whenever the air is cool enough for condensation to occur (Wainwright & Thornes, 2004). Winter rainfall in the Mediterranean is 3 times that of summer rainfall, but there is a gradient. At latitudes lower than 40° N, only 5% of the total precipitation falls during the summer months (Perry, 1997).

Malta is located below this line, putting it in the transition zone between humid, temperate Europe, and hot dry Africa (Perry, 1997). This zone is also characterized by high evaporation leading to drought conditions for approximately 5 months per year, putting a strain on water availability (Perry, 1997). When it does rain, it rains a lot; single day rainfall totals frequently make up the entire monthly or annual figures for many cities in the Mediterranean (Perry, 1997). This can cause problems with flooding and related damage, especially in urbanized areas with few permeable surfaces, or bad drainage design.

The previous section described the current climate of the Mediterranean; however, global climate is changing. It has been shown that global temperatures are rising (Bernstein et al., 2007), and as a result, local climate also changes. The Intergovernmental Panel on Climate Change (IPCC) defines climate change as any change in the state of the climate that can be identified using statistical tests of data that persists for an extended period whether due to natural variability or the result of human activity (Bernstein et al., 2007). While the climate has changed due to natural reasons in the past, current changes can be attributed to anthropogenic causes (Bernstein et al., 2007). The oceans have absorbed 80% of the heat added to the climate system and this has buffered the system and allowed the observed changes to be small to this point (Bernstein et al., 2007).

Anthropogenic climate change is driven by increases in atmospheric concentrations of greenhouse gases (GHG) and aerosols, land cover change, and solar radiation (Bernstein et al., 2007; Chapin, Randerson, McGuire, Foley, & Field, 2008). Increases in GHG have been driven by increases in global populations and income levels, leading to increasing emissions from energy, transportation, buildings, and agriculture (Bernstein et al., 2007). The oceans have been able to absorb a third of the anthropogenic CO_2 in the atmosphere and have transported that CO_2 from the surface to deeper waters (Hoegh-Guldberg & Bruno, 2010). However, as the

temperature difference between surface waters and deeper waters increases, less mixing is able to occur, reducing the amount of CO_2 that can be distributed to deep waters as well as reducing the nutrients that can be transported from deep waters to surface waters (Hoegh-Guldberg & Bruno, 2010). Since 1975, the energy of the upper 700 m of ocean has increased by 14 x 10^{22} Joules (Hoegh-Guldberg & Bruno, 2010).

Temperatures have been increasing by 0.2 ° C per decade over the last 30 years (Hoegh-Guldberg & Bruno, 2010), and by 2090-2099, the mean global temperature could increase up to 6.4 °C (Bernstein et al., 2007). Not only is the planet warming, but it is warming even faster than before. The increase of global mean temperatures from 1956 to 2005 is nearly twice that of the increase of temperatures between 1906 and 2005 (Bernstein et al., 2007). This increase in temperature has caused a number of observable changes to climate patterns on a global scale. There has been an increase in the number of hot days and nights recorded in conjunction with a decrease in cold days and nights and incidents of frost (Bernstein et al., 2007). There has been an increase in heat waves (Bernstein et al., 2007), including the 2003 heat wave that caused a number of heat related deaths in Europe (Christensen et al., 2007). There has also been a higher proportion of total rainfall coming from heavy falls. This means that storms and heavy rains are increasing (Bernstein et al., 2007). Warmer oceans drive more intense and frequent storms; storms are nature's way of releasing energy, so an increased temperature means there is increased energy, and therefore more storms (Hoegh-Guldberg & Bruno, 2010).

Model predictions for the Mediterranean region suggest that it will get hotter and drier. There are a number of different model scenarios, but the scenario used in this research was primarily the A1B scenario (Bernstein et al., 2007). This scenario describes rapid economic growth, population highs in the middle of the century and declining thereafter, and rapid development and introduction of new technologies. The A1B scenario assumes that new energy

needs from these changes are produced by a balance between fossil intensive and non fossil fuel sources (Bernstein et al., 2007). Using the A1B Scenario, mean annual temperatures in the Mediterranean are expected to increase by 2.5 – 3° C by the 2090-2099 decade (Christensen et al., 2007). Summer temperatures are expected to increase more than winter temperatures (Christensen et al., 2007). There is high confidence that semi arid areas like the Mediterranean will show decreases in precipitation, and consequently water resources will be strained (Bernstein et al., 2007). While models disagree on the magnitude and geographical details of a precipitation change, only one model out of 21 did not show decreasing precipitation (Christensen et al., 2007). The A1B scenario predicts annual precipitation will decrease by 15 – 20% (Bernstein et al., 2007; Christensen et al., 2007). Precipitation has already started to decline, with a decrease of precipitation levels between 1900 and 2005 in the Mediterranean region (Bernstein et al., 2007). The Mediterranean has already seen years with more evaporation than freshwater inputs from precipitation (Wainwright & Thornes, 2004). In addition to the total precipitation decreases, models also predict that the number of precipitation days will also decrease (Christensen et al., 2007). The combination of increasing temperatures and decreasing precipitation lead to conditions that increase the drought risk (Christensen et al., 2007). The IPCC finds that it is very likely that hot extremes, heat waves, and heavy precipitation events will become more frequent in the Mediterranean (Bernstein et al., 2007). Runoff into the Mediterranean is likely to decrease by 40%, meaning that there will be even fewer freshwater inputs, so the Mediterranean Sea will become more dense, potentially affecting circulation patterns in the Mediterranean as well as the Atlantic Ocean (Bernstein et al., 2007; Robinson, Leslie, Theocharis, & Lascaratos, 2001; Wainwright & Thornes, 2004).

These climate changes will have an effect on the people living in the region through agriculture, water supply, energy needs and health (Bernstein et al., 2007). Malta is especially vulnerable because of its issues with fresh water, poor capture and drainage systems,

dependence on tourism, and small size. According to the 4th IPCC Assessment, *"by mid century, climate change is expected to reduce water resources in many islands to the point where they become insufficient to meet demand during low rainfall periods."* page 30 (Bernstein et al., 2007). On Malta, this period of low rainfall also coincides with an annual influx of 1.2 million tourists who increase the demand for water and strain resources further (Schembri, Deidun, Mallia, & Mercieca, 2005).

Anthropogenic climate change is also having and will have far reaching effects on ecosystems and ecosystem services. Current data are limited by a lack of geographic balance between data collection activities and observations in developed and developing nations (Bernstein et al., 2007) as well as a lack of ecosystem balance, as 95% of climate change literature focuses on terrestrial impacts(Hoegh-Guldberg & Bruno, 2010). Despite this, several generalizations of current observations and predictions for the future can be made. Increasing global temperatures have caused an increase in ocean volume and associated sea level increases due to thermal expansion (Bernstein et al., 2007; Hoegh-Guldberg & Bruno, 2010). This has impacts on the ranges of habitat building species like coral and sea grass, flooding and damage to coastal infrastructure, and availability of land and fresh water for many small islands (Bernstein et al., 2007). Rising sea level may also alter local circulation patterns, which in turn influence oxygen and nutrient levels, sediment transport, species ranges, and migratory patterns (Bernstein et al., 2007; Hoegh-Guldberg & Bruno, 2010). In addition to causing rising sea level, increasing temperatures can change the suitability of habitat for a species as it approaches the threshold of temperature tolerance. There is already evidence that species ranges, including those of pelagic fish, are moving northward as tropical waters are becoming too hot for many species (Hoegh-Guldberg & Bruno, 2010). This is true for viruses, bacteria, and fungi that cause diseases as well, which can pose health risks for the human and other populations (Bernstein et al., 2007; Hoegh-Guldberg & Bruno, 2010).

Marine systems are intricately linked with climate and weather systems. Changes to either system can have far reaching effects on both ecosystems and ecosystem services and consequently on human economies. With the increase in fossil fuel use for energy, major land use changes, and an increasing human population, the ability of humans to alter the climate system has increased dramatically. Global climate change is occurring and will cause extensive changes to ecosystems over the next century. The Mediterranean region is expected to get hotter and drier. Adapting to these conditions is likely to be a costly but necessary outcome (Bernstein et al., 2007).

2.3 Provisioning of Nursery Habitat

When dealing with fishery issues, primary considerations are the requirements of a fish and its habitat (Levin & Stunz, 2005). Fish require quality habitat for reproduction, growth, migration, and persistence of a species (Harmelin-Vivien, Harmelin, & Leboulluex, 1995; Levin & Stunz, 2005). The growth stage between settlement and recruitment is one of the most important stages, as small changes to the population at this stage can have much larger impacts on the size of the adult population (Harmelin-Vivien et al., 1995; Levin & Stunz, 2005). Successful settlement and recruitment is essential for the replenishment and maintenance of fish stocks (S. Bussotti & Guidetti, 2011).This growth stage uses habitats known as nursery habitats. Nursery habitat was selected as the marine ecosystem service for the supporting category in this study because it is an often overlooked, but essential part of fisheries management.

Costanza *et al* identify the nursery habitat service as "Refugia" with the ecosystem function as "habitat for transient and resident populations." (Costanza et al., 1997). In general, nursery habitat is understood to be areas where juvenile fish live and grow; however, this definition is too broad for this study. Beck *et al* add some stipulations to the general definition,

requiring nursery habitat to be separate from the habitat in which a species lives as an adult (Beck et al., 2001; Beck et al., 2003; Heck, Hays, & Orth, 2003). This means that not all species would have a nursery habitat. From a management perspective, this makes sense, because for species without separate habitats for adults and juveniles, resources that are allocated to the adult habitat protect the juveniles as well.

Beck *et al* want to define a nursery habitat as the habitat that has a higher contribution to the adult population by area (Beck et al., 2001; Beck et al., 2003). It is not just enough to have juveniles present within the habitat, but the habitat must provide something that helps successfully raise the juveniles to adults. The habitat must do this better than other areas where the juveniles are found. With this definition, the density of juveniles is NOT an indicator of the nursery value of the habitat (Beck et al., 2003). More important than density are factors such as survivorship and growth rates, both factors that are influenced by habitat (Heck et al., 2003). Other factors that can influence the value of a nursery habitat include distance to larval supply and adult habitat, competition, predation level, chemical factors such as dissolved oxygen and salinity, landscape fragmentation and water depth (Beck et al., 2001). The definition provided by Beck *et al* is limited because while it selects the most productive areas, it does not always include the area that produces the most adults. It is limited by the per area requirement (Dahlgren et al., 2006). To use an example from Dahlgren *et al* (2006), if you have two habitats and Habitat A covers 90% of the study area, then Habitat B covers 10% of the area. Habitat B is more productive per unit area, producing 15% of the fish that reach adulthood, and is thus considered the nursery habitat according to Beck. However, Habitat A still produces 85% of the adults, so it cannot just be ignored (Dahlgren et al., 2006). Dahlgren would rather use the "Effective Juvenile Habitat" which he defines as the habitats that contribute the most to adult stock. The problem here is that with limited resources, it may be difficult to preserve a large habitat like Habitat A, and while Habitat A may provide more fish, if a marine protected area

can only be a small proportion of the assessed area, protection should be afforded to the area that will produce more.

The idea of rating the adult production value of habitats meets with a number of difficulties. The first is that there are very few data available about settlement and recruitment processes, especially in the Mediterranean (Biagi, Gambaccini, & Zazzetta, 1998; Harmelin-Vivien et al., 1995). Even more limited are the data on juvenile survival, habitat specific survival and successful movement from juvenile to adult habitat, which are required to make value measurements about nursery habitat (Levin & Stunz, 2005). What data exist are rarely consistent between regions (Beck et al., 2003; Harmelin-Vivien et al., 1995). There are several reasons why the data are not available. Marine species have a wide distribution and respond to changing environmental parameters by changing their habitat and distribution pattern (Valavanis et al., 2008). These changing parameters can be anything from tidal action and light penetration to physiochemical factors like dissolved oxygen or temperature. This makes it difficult to identify which habitat the fish is using as it is probably using a mosaic of habitats. Individuals move between habitats and can receive different benefits from each habitat they reside in or near (Beck et al., 2003). Often, nothing more specific than 'nearshore' can be identified as the nursery habitat, or if a habitat can be identified regionally, local variation makes studies outside of the immediate area inadequate for value determinations (Beck et al., 2003).

Identification of habitat used is also made difficult by the limitations of survey techniques. Most often, SCUBA divers are used to identify what fish are present in a habitat. This requires divers to be extremely familiar with both juvenile and adult morphological characteristics, which is often difficult when juveniles do not look anything like their adult forms. Also, this direct observation method could have the effect of scaring away some fish that may have been present before divers entered the water and forcing other fish into hiding.

Examining juvenile habitat is possible by capturing adults and using isotopes or other natural and artificial markers to identify juvenile habitat (Dahlgren et al., 2006). This results in a proportional contribution of habitats for each individual (Beck et al., 2003). However, by this process, individuals can be shown to receive benefits from habitats they never reside in via their prey (Beck et al., 2003). These difficulties have made it extremely difficult to identify juvenile habitat in general, as well as in Maltese waters.

There is wide variation in the habitat preferences and life histories of major groups of Mediterranean fish and shellfish. Mediterranean species often have a juvenile stage where they reside in benthic inshore habitats less than 12m before they move offshore as adults to reproduce and live (Biagi et al., 1998; Harmelin-Vivien et al., 1995; Millennium Ecosystem Assessment, 2005). The length of time for this juvenile period and preferred habitat vary widely. Biagi *et al* found that some fish stay in shallow habitats for only 1-2 months, while others remained for almost a year. These shallow areas are attractive because there is abundant food and lower predation than in adult habitats (Dahlgren et al., 2006). Juveniles generally indicate a preference for habitat with increased structural complexity (Beck et al., 2001; Beck et al., 2003; S. Bussotti & Guidetti, 2011; P. Guidetti, 2000b; Heck et al., 2003). The 3-dimensional structures allow for more and better refuge from predators, which allows more time for feeding. This is facilitated by the fact that more structural complexity allows for more surface area for attachment, providing the juvenile fish with a greater source of food. So the juveniles have more food to eat and more time to eat it, increasing growth rates, which in turn increase survivorship to the adult stage (Heck et al., 2003). Heck and Crowder found in 1991 that even between two seagrass habitats, complexity decreased predation suggesting that ecosystems that have increased complexity would have a higher value as a nursery ground (Beck et al., 2001). In Malta, the nearshore habitats with increased complexity are beds of *Posidonia oceanica*, rocky algal reefs, and maerl beds.

Table 1 shows 30 common commercial landings in Malta. An extensive literature review was done to identify juvenile habitat. A listing of included terms is available in the glossary. In many cases, nursery habitat could not be identified further than 'inshore' or 'continental shelf'. Where habitat could be identified, the most common habitats are floating or drifting objects. Other important habitats are seagrass beds, rocky algal reefs and maerl beds. From the table it is possible to confirm that there is a wide variety of habitats necessary to support the juvenile populations of Malta's commercial fish. Because of the lack of detailed data for many of the fish, as well as a lack of local published data on nursery habitat, this project will focus on Maltese maerl beds, seagrass beds, algal reefs, and inshore areas shallower than 12 m as potential habitat.

Globally, seagrasses are thought to be a key nursery habitat (Malta Environment and Planning Authority, 2002; Millennium Ecosystem Assessment, 2005; Orth et al., 2006). In the Mediterranean, seagrass beds are thought to be responsible for 80% of the annual fish yield (UN Environment Program, 2004). However, the identification of seagrass beds in the Mediterranean as nursery habitat seems to be based on measurements of juvenile density rather than studies of survivorship. There are two important types of seagrasses that grow around Malta: *Posidonia oceanica*, and *Cymodocea nodosa*. *C. nodosa* is a pioneering species that grows between 0 and 60m in the Mediterranean (Borum & Greve, 2004). It can easily colonize bare sand patches (Borum & Greve, 2004). *P. oceanica* covers approximately 25% of bottom between 0-45m in the Mediterranean, though it can be found up to 60m if the water is clear (Krause-Jensen, Almela, Cunha, & Greve, 2004) *P. oceanica* habitat is protected under the EU Habitats Directive (92/43/EEC) and the Maltese LN 311 of 2006 equivalent (European Union, 1992 updated 2007). Seagrasses are thought to be important nursery habitat because there are higher

Maltese name	English name	Scientific Name	Mean kg 03 - 05	Nursery habitat(s)	Source#
Lampuki	Dolphin Fish	*Coryphaena hippurus*	475,625	Pelagic (water column), floating/drifting objects, oceanic (off-shelf), occasionally neritic (coastal/on-shelf)	1
Tonn, juv. Tunnaggi	Bluefin Tuna	*Thunnus thynnus*	252,253	Pelagic oceanic, occ. Neritic	1
Pixxispad	Swordfish	*Xiphias gladius*	210,391	Pelagic oceanic, occ. Neritic; Water above 24° C	1
Gambli	Shrimps/Prawns	*Parapenaeus longirostris or Plesionika spp or Aristaeorpha foliacia*	31,026	Benthic neritic, on organic matter-rich continental shelf break 100-200m depth	2
Dott/Hniezer	Stone Bass	*Polyprion americanum*	29,247	Attracted to floating objects	1
Mazzola	Dogfish	*Squalus acanthias*	18,673	Pelagic neritic, 50-150 meters or depth over shelf, in schools by size until mature, then by size and sex	3
Vopi	Bogue	*Boops boops*	18,673	Pelagic neritic, <15m depth has highest densities; over what substrate preferences uncertain	1,4
Cippullazz	Scorpionfish	*Helicolenus dactylopterus*	11,286	Pelagic neritic, deep water over shelf	1
Fanfri	Pilot fish	*Naucrates doctor*	10,118	Associated with Jellyfish and drifting seaweed	1
Alonga	Albacore	*Thunnus alalunga*	9,862	Pelagic oceanic, may concentrate in schools at temperature discontinuities/fronts	1,5
Pagri	Common Sea Bream	*Pagrus pagrus*	6,668	Seagrass Beds	1
Raj	Skate	*Raja clavata*	5,646	Benthic neritic, sandy and rock/sandy bottoms, juveniles potentially spawned in <20 meter water and move deeper with age	1,6
Kavalli	Mackerel	*Scomber japonicus*	5,586	Pelagic neritic, coastal/over shelf, schooling begins at 3 cm	1
Qarnit	Octopus	*Octopus vulgaris*	5,206	Benthic neritic, nearshore rocky areas, hide in middens	7, 17
Tumbrelli	Frigate Mackerel	*Auxis thazard*	4,779	Pelagic oceanic/neritic, near surface	1
Muruna	Six-gill Shark	*Hexanchus griseus*	4,597	Demersal neritic, shelf/coastal waters, shallower than adults	8
Accola	Amberjack	*Seriola dumerlii*	4,594	Pelagic oceanic/neritic, floating plants and debris or small schools	1
Merluzz	Hake	*Merluccius merluccius*	3,887	Demersal neritic, over shelf waters, crinoid beds at shelf break preferred	9, 10
Skorfon	Scorpion fish	*Scorpaena notata*	3,706	Demersal neritic, shelf/coastal waters in maerl/macroalgae beds	1,11
Trill	Red Mullet	*Mullus surmuletus or Mullus barbatus*	3,222	Demersal neritic, shelf/coastal waters, muddy/rocky bottoms; M. sumuletus juveniles use any sublittoral habitats	1, 12, 13
Sargi	White Bream	*Diplodus sargus*	2,768	Pelagic neritic, coastal waters; very shallow water (0-2 meters) with gently-sloping rocky substrate, shallow sheltered coves	13,14
Sawrell	Horse Mackerel	*Trachurus trachurus*	2,509	Pelagic neritic, schools of pelagic juveniles eat copepods, attracted to floating objects; seen at crinoid shelf break	15
Klamari	Squid	*Loligo vulgaris*	2,448	Pelagic neritic	16
Lipp	Ling	*Phycis blennoides*	2,012	Neritic, Coastal waters found on shelf, Demersal	1
Sicc	Cuttlefish	*Sepia officinalis*	1,754	Sandy Substrates with algal or seagrass beds <60m	17
Pagell	Pandora	*Pagellus erythrinus*	1,550	Inshore, Neritic, Demersal, mud, sand or rock,	1
Bazuk	Blue Spotted Bream	*Pagellus bogaraveo or Pagellus acarne*	1,340	Inshore, benthy pelagic, neritic,near coastal, nearshore, sea grass beds Neritic	1
Kubrit	Little Tunny	*Euthynnus alleteratus*	1,182	Neritic waters inshore, Sand, Mud, and eel grass	1
Makku	Pellucid Sole	*Aphia minuta*	1,142	Pelagic, shallow waters, neritic, Sand and rocky bottoms, does not settle on seagrass beds	18
Denci	Dentex	*Dentex dentex*	1,054	Neritic, Rocky bottoms and Posidonia beds	19

Table 1: List of Commercial Maltese Fish and Identified Nursery Habitat *Landings data are from {{178 Malta Fisheries Department 2006}}
A complete list of sources for this table is found in Appendix C

juvenile densities present on seagrass beds when compared to unvegetated habitat nearby (Heck et al., 2003). The 3-dimensional structure provided when the seagrasses form thick tall beds creates numerous hiding places from predators (Terrados & Borum, 2004). Based on studies comparing seagrass beds to other areas with a complex structure, it is thought that the 3-dimensional assemblage is what makes seagrass beds good habitat rather than some inherent characteristics of the seagrasses themselves (S. Bussotti & Guidetti, 2011; Heck et al., 2003). Malta has an extensive range of reticulated and continuous seagrass meadows on the northeastern side of the island (J. A. Borg & Schembri P.J., 2002)

Rocky algal reefs are often overshadowed by seagrass beds by those determining nursery habitats. These areas however also are able to provide rich nursery habitat for fisheries (Millennium Ecosystem Assessment, 2005). A number of experiments in the Mediterranean show that fishes prefer macro-algal beds to *Posidonia* beds. Experiments by Harmelin-Vivien *et al* show that sparid fishes recruit to hard surfaces with macro-algal growth over seagrass beds (Harmelin-Vivien et al., 1995). Biagi *et al* determined that seagrass beds played a smaller role in recruitment and settlement processes than temperate subtidal rocky reefs (Biagi et al., 1998). Areas with greater algal cover generally produce larger fish (Biagi et al., 1998). This is again most likely attributed to the complexity of the 3-dimensional structure that the algae produce. In Malta, the shallow rocky reefs are dominated by *Cystoseira* sp. and *Dictyopteris* sp. (Stevens et al., 1995), though they frequently show zonation, with light loving plants closer to the surface, and shade loving plants found deeper (J. A. Borg & Schembri P.J., 2002). These reefs can be found along most of Malta's coastline and deeper where there are hard surfaces.

Maerl beds are formed from living and dead accretions of unattached calcareous algae called rodoliths (Barbera C. et al., 2003). As maerl is formed by algae, the rodoliths need light to grow, however they are outcompeted by seagrass and macroalgae in shallower waters, so

maerl beds are usually found in areas with lower light levels. In the Mediterranean, maerl has been found up to depths of 180m (Barbera C. et al., 2003). Maerl assemblages come in a variety of shapes as they grow forming complex 3-dimensional structures (Barbera C. et al., 2003). These assemblages are able to create enough structure to support a high level of biodiversity. In Malta, maerl beds have been known to support 400 species, including 100 types of mollusc (Barbera C. et al., 2003; J. A. Borg & Schembri P.J., 2002). Because of the structure and high biodiversity, maerl beds have been identified as Maltese nursery habitat. In Malta, the full extent of maerl beds has never been established and mapped. There are two known and mapped sites, one south of the island and one off the north east coast (J. A. Borg & Schembri P.J., 2002). The northeastern bed has been mapped. It was determined to be approximately 20 km^2 (J. A. Borg & Schembri P.J., 2002).

While seagrasses may be the most sensitive, all three of these habitats are encountering the same threats. These threats include increasing turbidity, physical damage from building, fishing and anchoring, climate change, and invasive species (Duarte, Marba, & Santos, 2004; Millennium Ecosystem Assessment, 2005; Orth et al., 2006). Seagrasses, algae, and maerl are all photosynthetic organisms; they require light to reach their depth. When there are increases in turbidity less light is able to penetrate as the particles in the water absorb or reflect the light. This does not allow as much light to reach the surface of the organisms, which decreases growth rates. Seagrasses require between 11 and 25% incident radiation for growth (Duarte et al., 2004; Orth et al., 2006). When compared to other angiosperm species, which require only 1% incident radiation, this explains why seagrasses are used as an indicator of ecosystem health (Orth et al., 2006). Even small changes in water clarity will affect the seagrass beds. Light penetration decreases when there is an influx of suspended sediment, something that occurs in Malta: after it rains, after SCUBA divers enter the water, as fish farms are built, and when new developments and infrastructure on the coast change sediment patterns (Barbera C. et al., 2003;

Duarte et al., 2004; Millennium Ecosystem Assessment, 2005; Orth et al., 2006). Nutrient loading from fish farms, sewage outflow, and runoff can also cause decreased light attenuation (Barbera C. et al., 2003; Duarte et al., 2004; Orth et al., 2006). The increased nutrients spur microbial and plankton growth that further decrease the amount of light reaching the bottom and can cause dramatic changes to the planktonic community.

Physical changes to seagrass beds, algal communities and maerl beds are also a serious threat. Trawling is one of the most destructive legal fishing practices (Tudela, 2004). Otter trawling is allowed year round within Malta's fishery management zone, though only 15 trawlers are licensed (Darmanin & Dimech, 2007). In addition to damaging the bottom, trawling also captures juveniles living in these habitats without regard to minimum size limits, further affecting the nursery value of these areas (Tudela, 2004). Trawling can damage rodoliths, break the maerl (decreasing the rugosity of the area) and bury the growing end of thalli (Barbera C. et al., 2003). The damage is unlikely to be repaired before the area is trawled again as rodoliths grow very slowly (Barbera C. et al., 2003). Seagrass beds and algal reefs are likely to experience broken and detached leaves and damage to root systems and holdfasts (Duarte et al., 2004; Orth et al., 2006). The effects of anchoring are similar to the effects of trawling. While anchoring is much less destructive than trawling, the intensity of repeated anchoring over small areas can be extremely detrimental to an ecosystem. Scars from anchoring in *Posidonia* beds could take decades to repair (Duarte et al., 2004; Krause-Jensen et al., 2004).

The effect that climate change will have on these communities is extremely uncertain. Increased CO_2 is likely to be advantageous for seagrass beds when competing with other types of algae (Duarte et al., 2004; Orth et al., 2006). Increasing temperatures are also likely to increase growth in all three habitats, unless it is accompanied by increasing microbial activity.

Increased UV and storm activity would negatively affect seagrass and algal communities, and the expected increase of invasive species is likely to also be detrimental (Duarte et al., 2004; Orth et al., 2006). The invasion of the Mediterranean by *Caulerpa taxifola* has already shown a sign of affecting these habitats as it has been competing with Posidonia for space and resources (Duarte et al., 2004). At present, there is little research into how maerl communities will adjust to changing climates (Barbera C. et al., 2003). The dynamic interactions of these three communities with the physical environment are not understood well enough to make predictions as to how they will react to a changing climate.

The lack of data that can be used for identifying nursery habitat underscores the difficulty in understanding the complex interactions of juvenile fish and their environment. Despite the difficulties in identifying juvenile habitat, good fisheries management must include protection for these areas. In looking at the data on Maltese and other Mediterranean species, it becomes more obvious that managing a mosaic of habitats will protect multiple species better than preserving one or two (S. Bussotti & Guidetti, 2011). In light of the difficulties in identifying essential nursery habitat, it is essential to conserve a mosaic of structurally complex environments to facilitate juvenile growth and survivorship to the adult stage.

2.4 Tourism and Recreation

The cultural ecosystem service examined in this study is recreation. On Malta, it is important to note that due to the large influx of tourists annually, a discussion of recreation must include a discussion of tourism as well. The two will be discussed concurrently as recreational activities of tourists and residents are assumed to be similar, and as such, their impacts will also be similar. While the activities are alike, the spatial and temporal characteristics may differ; however, this will not be directly addressed in this study.

2.4.1 Description of Recreation and Tourism

Recreation and tourism are social constructs that often are tied to nature and the environment. Tourism is the world's largest industry, generating 11% of all jobs and more than 5.3 trillion dollars a year (Millennium Ecosystem Assessment, 2005; Schloegel, 2007). Recent improvements in technology have made oceanic and coastal areas more accessible, causing ocean and coastal tourism to be the fastest growing area of the tourism industry (Burgin & Hardiman, 2011; Hall, 2001; Luna, Pérez, & Sánchez-Lizaso, 2009). As such, an understanding of the potential benefits and disadvantages of coastal and marine tourism is necessary for good planning and management to occur. Planning and management of the tourism industry is essential as tourism interacts with a number of industries and disciplines. During the 1998 Year of the Ocean, the US National Oceanic and Atmospheric Administration released a report on coastal tourism stating:

> *"Virtually all coastal and ocean issue areas affect coastal tourism and recreation either directly or indirectly. Clean water, healthy coastal habitats, and a safe, secure, and enjoyable environment are clearly fundamental to successful coastal tourism. Similarly, bountiful living marine resources (fish, shellfish, wetlands, coral reefs, etc.) are of critical importance to most recreational experiences. Security from risks associated with natural coastal hazards such as storms, hurricanes, tsunamis, and the like is a requisite for coastal tourism to be sustainable over the long term"*(National Oceanic and Atmospheric Administration, 1998)

The coastal tourism industry faces the challenge of being a diversified group with a large number of competing stakeholders. It is essential that there be a coordinated management plan to prevent the destruction of the coastal environments, and along with them, the tourism industry itself.

To discuss an industry as broad as coastal tourism, it is important that there are well-established definitions and limits to the investigation. Many of the broad definitions of tourism are the same. Acott *et al* define tourism as a temporary change of place. Schoegel clarifies that tourism is an activity that causes a person to leave their natural environment, but includes recreation, business and leisure as possible reasons for travel (Schloegel, 2007). Rees *et al* define marine recreation as "*the refreshment and stimulation for the human body and mind through the perusal and engagement with living marine organisms in their natural environment* (Rees, Rodwell, Attrill, Austen, & Mangi, 2010)." While the description of recreation is eloquently put, it is not necessary to interact with or observe marine life to be participating in coastal and marine recreation. A number of coastal activities use adrenaline or relaxation as drivers and do not require interaction with wildlife at all. Hall *et al* define coastal tourism as all leisure and recreational activities that take place in the coastal zone and offshore waters (Hall, 2001). This definition provided by Hall *et al* is perhaps the most comprehensive, and the one this study will be using. The scope of this includes development of hotels and restaurants, infrastructure for supporting the facilities and tourists, and recreational activities. While all of Malta is arguably located within the coastal zone, for the purposes of this research, only activities taking place within the water, on top of the water or in areas directly adjacent to the water will be considered.

Four types of stakeholders are involved in tourism: (i) tourists, (ii) the resident population, (iii) organizations representing those providing activities, housing, food and other tourist requirements and (iv) the natural environment and those who speak for it (Cater, 1995). All of these groups want tourism to be sustainable. Tourists, because it lets them visit new places; residents, because tourism provides jobs and economic growth; the tourist organizations, because they make money; and the government agencies and NGOs representing environmental interests, because if managed correctly, tourism is not as damaging as other industries (Hall,

2001; Milazzo, Chemello, Badalamenti, Camarda, & Riggio, 2002). Sustainable tourism and recreation require clean air and water, safe and secure environments, and good management practices that facilitate public access, protect wildlife and ecosystems, and site facilities so that they maintain the recreational, aesthetic, and environmental value of the area (Millennium Ecosystem Assessment, 2005; National Oceanic and Atmospheric Administration, 1998). However, the variety of stakeholders has made it difficult for policy makers to develop policies and coordinate activities for the tourism sector (Hall, 2001).

Many tourism and recreational activities such as scuba diving, recreational fishing, and bird watching depend on the presence of wildlife (Rees et al., 2010). The wildlife is the attractive feature. Without the presence of that wildlife, tourists will go to other locations. While the link between tourist attendance and condition of environment has not been analyzed on a global level, on a local level, there is a strong correlation between ecosystem health and tourism revenue (Millennium Ecosystem Assessment, 2005; National Oceanic and Atmospheric Administration, 1998). For example, Jamaica and Barbados both showed a decline in tourist visitors when coral reefs were damaged. This led to unrest and further declines as tourists no longer felt safe (Millennium Ecosystem Assessment, 2005). When an area stops being safe, or stops being aesthetically pleasing, tourists do not continue to visit (National Oceanic and Atmospheric Administration, 1998).

Rees *et al* consider marine tourism to be a benefit received from direct or indirect non-consumptive interactions with the marine environment (Rees et al., 2010). The idea that tourism is non-consumptive however, is wrong. People value the coastal zone for open spaces, attractive views, and good beaches (Millennium Ecosystem Assessment, 2005). However crowding, increased development, and associated degradation of these areas occur as more tourists arrive, making the area less attractive to tourists and decreasing tourism revenues.

Tourism is in fact an activity that consumes large amounts of resources, including space. Tourists also consume significant amounts of essential resources such as water and energy. The consumption and resulting degradation is recognized as an effect of poorly planned tourism development.

Tourists themselves are largely unaware of the impact that tourism as a whole can have on a place. Tourists are sensitive to spatial patterns but miss the temporal aspect of their impacts as they are concerned with the attractiveness of the area for the short time they are present and do not sense their impact when combined with other short term guests(Petrosillo, Zurlini, Corlianò, Zaccarelli, & Dadamo, 2007). Even if they sense their impacts, tourists perceive their impacts in the short term and act accordingly. They do not perceive the compounded effects of several thousand visits (Petrosillo et al., 2007). The point here is that one tourist's impacts may be minimal, but the intensity of use enlarges the possibility of degradation. The nature of tourism is such that use of recreational areas can be extremely intense during a few months and almost nil for the rest of the year. If the ecosystems are unable to recover during the off months, the ecosystems may be degraded to the point where the area is no longer attractive as a tourist site (Garcia & Servera, 2003). So tourism is able to be nonrivalrous or renewable to a point, but once a critical number of visitors has been reached, it becomes rivalrous and degradation occurs (Davis & Tisdell, 1995). The World Tourism Organization has developed a number of indicators to assist in identifying when degradation is occurring. These include: use intensity (persons per meter of accessible beach), species counts (number of species, change in composition), pollution levels (fecal coliform, heavy metal counts, etc.), and accident rates (National Oceanic and Atmospheric Administration, 1998) (WTO, 1996).

Besides concentration of use, urbanization is an increasing problem for coastal regions. Urbanization disrupts the natural system that supports environmental function. When the natural system is disrupted there are consequences for the long-term survival of coastal ecosystems. As our understanding of the complex processes governing this natural system is limited, our understanding of how a development will disrupt the system is also lacking (Hall, 2001). Even where there is enough knowledge to detect the effects, there is often not the foresight or political will to stop such a development from occurring. One of the most obvious processes that are interrupted is the delivery of sediment to beaches (Garcia & Servera, 2003; Hall, 2001; Millennium Ecosystem Assessment, 2005). When beachside developments and developments further inland prevent sand from being transported to the beaches, the beaches experience erosion, making the beaches smaller and less desirable as a tourist destination. This impact often results in expensive restoration projects paid for by the government, which understands that beaches are essential for the continuation of the coastal tourism industry. Other urbanization structures like concrete piers and seawalls can disrupt sediment patterns and local currents as well, causing problems for offshore habitats as they can be buried (Garcia & Servera, 2003; Hall, 2001; Millennium Ecosystem Assessment, 2005). These structures also increase vulnerability to violent storms and wave action because they are unable to buffer the waters energy as natural systems do. Another issue with urbanization is that development removes the current habitats that are present, often ones that are of high quality and that are providing a disproportionate amount of ecosystem services to local populations (Hall, 2001).

The strain that tourists put on the provision of fresh water is also a major issue for many coastal areas. Coastal areas, especially small islands in the Mediterranean region often face issues with provisioning fresh water. Tourists have been known to consume approximately twice the amount of water as residents placing additional strain on local water systems (Garcia & Servera, 2003). Hotels in general also use substantial quantities of water for laundry, and

cleaning services. It has been estimated that a luxury hotel can use 600L of water per guest per night (Perry, 2000). This can lead to additional problems such as salt water infiltration into groundwater aquifers, or substantial energy consumption in areas where water is produced from desalinization (Hall, 2001) – the latter is a highly energy intensive process. On Malta 20% of energy produced is used to make water through reverse osmosis (Mangion, 2001). If problems become severe, this could eventually lead to friction between the local population and the tourism authorities and interests (Perry, 2000). As climate change is expected to exacerbate this issue, water management will likely be a major constraint in Mediterranean plans for the management of sustainable tourism.

Tourism is one of the more important industries on Malta. With few resources but a pleasant climate and access to the ocean, it is easy to understand why tourism forms such a large part of the Maltese economy. In 2010, total tourism expenditures were more than 1.1 billion Euros (Said). 2009 tourism expenditures were substantially lower than the 2004 – 2010 mean, but were still responsible for 16% of Malta's GDP (National Statistics Office, 2010; Said). In other years, the tourism fraction of the economy can be as high as one fourth of GDP and employment (M. Cassar, 2003; Mangion, 2001). Having such a large proportion of its economy dependent on tourism is potentially hazardous as Malta risks becoming reliant on an industry that could potentially destroy itself through overuse. The seasonal aspect can also be stressful for tourism operators and policy makers in Malta. Many operators lose money during winter months, hoping that they can make it up during the summer period (Mangion, 2001). Operating at a loss and hoping to even out profits at the end of the year is not sound economic policy. Climate change is expected to lengthen the peak season and boost tourism in shoulder months, which may prove beneficial to the industry (Perry, 2000; Zarb, 2011). The main industry focus for Maltese tourism is accommodation; however, the agriculture, food and

beverage production, fuel consumption and service industries are also important to the tourism industry.

The tourism industry in Malta has grown in an unplanned manner, reacting to market demands resulting in uncontrolled growth in tourism development (Mangion, 2001). Also, the large number of illegal developments along the coast that are forgiven rather than penalized is a problem (M. Cassar, 2003). In an area where 30% of the coastline (without Gozo) is built up, this causes a number of environmental issues, as well as changing the character of the area (Mangion, 2001). One of the major threats to tourism is urbanization as it decreases the attractiveness of the islands, chasing tourists away, and putting an increasing strain on already limited resources (Mangion, 2001). MEPA's Coastal Strategy Topic Paper describes it this way:

> *"Over 1 million tourists require accommodation and recreational facilities, which over time have taken up considerable stretches of the coast, particularly hotels and beach concessions. The benefits obtained from such a location are limited and short-lived, since densely built-up coastal areas no longer provide the tourism product originally promoted."* (Malta Environment and Planning Authority, 2002)

Tourism in Malta is largely constrained by the limited amount of land and resources available. Tourism is forced to compete with residents and other industries for space, transportation, water, and energy. A number of infrastructure facilities such as power stations, reverse osmosis plants and sewage treatment centers need to be located on the coast (Malta Environment and Planning Authority, 2002). Population density in Malta is already extremely high, and the annual inflow of 1.3 million tourists means that during summer months tourists can outnumber residents on the island (Pollacco, 2003; Said). In the summer of 2001, the population density rose to 15,000 people per km^2 (Pollacco, 2003). This leads to high densities of people on beaches and public transportation and high energy and water requirements during

the summer. Direct tourism activities are responsible for 8% of energy use on Malta (Mangion, 2001). Studies have shown that the average tourist on Malta uses 1.5 times the amount of energy and water of a local resident (Mangion, 2001). Tourism consumes 8% of water resources that are expected to decrease as climate change effects become more prominent. Energy use is also supposed to increase as climate becomes warmer as tourists will increasingly view air conditioning as a necessity (Perry, 2000). As Malta is still entirely dependent on fossil fuels for energy, this could be costly environmentally as well as economically. The strain of tourism has the potential to substantially degrade Malta's resources if not managed properly.

To assist in the management and development of a strong, yet sustainable tourism industry, MEPA commissioned a study to establish the carrying capacity for tourism in Malta (Pollacco, 2003). The study was completed in 2001, before Malta's accession to the EU. MEPA defined carrying capacity as

> "*the maximum number of visitors that Malta and Gozo are able to host at the same time without suffering the destruction of the physical, economic, and socio-cultural environment and causing an unacceptable decrease in visitor satisfaction.*" (Mangion, 2001).

The idea of developing a carrying capacity was designed to manage visitor use with the finite resources available on the islands, a process that is difficult because tourism draws from a number of sources, products and services (Mangion, 2001). While carrying capacity is normally an ecological term, neither the definition nor the study actually seemed to take the environmental impacts of tourism into account. The study seemed to be much more focused on how tourism could be sustained economically, and while it mentioned the increase in resource use tourism requires, the study never mentioned plans for maintaining environmental stability or reducing resource use. Other policies that apply to the regulation of the coast and tourism

are the Environment Protection Act of 1991 (EPA), Development Protection Act of 1992 (DPA) and the Tourism Policy for the Maltese Islands (2007-2011).

The Tourism Policy for the Maltese Islands names the environment as one of its three pillars and mentions sustainability in two of its eleven policy objectives. The environmental focus in the report describes a number of ideas to maintain environmental integrity. These include: ensuring new tourism developments are not placed on sensitive habitats, keeping beaches clean as well as creating new beaches to relieve pressure on the natural ones, scuttling more wrecks as dive sites, enforcing spear-fishing laws, eliminating raw sewage disposal, maintaining proper siting for aquaculture facilities, and educating the public about local species (Ministry of Tourism and Culture, 2007).

While these policies sound ideal, there should be major concerns with at least two of the goals. By stating that they want to ensure new developments do not destroy sensitive habitats they overlook the possibility that any new development that is not part of the current urban landscape will inevitably cause damage to the existing ecosystems. A reduction in new developments would be significantly better for local habitats than any further development. Attempting to create artificial beaches in areas where there is no natural beach will cause a myriad of problems because of the geomorphology of Malta. Sediment losses may be high and will consequently severely damage the adjacent marine systems. This is not an adequate or practical solution to relieving the stress on natural beaches caused by overuse. Some of these goals have been practically and effectively applied. Malta's effort to eliminate the disposal of raw sewage at sea has been very successful. As of June 2011, Malta no longer pumps untreated sewage into the Mediterranean (*Three new wastewater treatment plants.*3 June 2011).

The primary reason for tourists to come to Malta is its location and climate. A study of residents of the UK showed that 80% of people listed better weather than can normally be found in the UK as their primary reason for taking a holiday (Perry, 2000). Malta has been marketed primarily as a sun sea and sand destination in both winter and more recently summer periods (M. Cassar, 2003; Ministry of Tourism and Culture, 2007; Zarb, 2011). However, the industry is now trying to alter marketing to attract tourists to the unique things Malta can offer including environmental and marine heritage experiences (Zarb, 2011). This is in hopes that they can attract more repeat tourists and encourage tourists to visit in the shoulder months instead of just the summer (Zarb, 2011). It is expected that with climate change, tourism in the shoulder months may increase as summer temperatures become too warm (Perry, 2000; Wainwright & Thornes, 2004)

Tourism is concentrated in a few areas on the island however, tourists travel throughout the island for different activities and points of interest. This requires infrastructure to accommodate them. Studies on Malta have shown that 80% of tourists use public transportation during their time in Malta (Mangion, 2001). The recent conversion of the bus system was not extraordinarily successful in alleviating associated problems in its initial stages; however its effects on tourism in the long term remain to be seen. Accommodation is centered on the coast with the most popular tourist areas being the St Julian's/Sliema and Bugibba/Qawra areas on Malta and the Mgarr, Xlendi and Marsalforn areas in Gozo (Mangion, 2001; Pollacco, 2003). Cultural activities are centered in the old cities at Valletta and Mdina in Malta and Rabat in Gozo (Mangion, 2001; Pollacco, 2003). The limited sandy beaches are quite popular. Residents and tourists often compete for space during the summer months (Mangion, 2001). Important marine and coastal-based activities that residents and tourists participate in were identified for this study. These activities are beach use, scuba diving, and boating.

2.4.2 Beach Use:

Beaches are perhaps the most important habitat for coastal recreation. Malta has both rock and sand beaches; in fact, almost anywhere that has access to the water is used as a beach. While the 'rock beaches' are not technically beaches as they do not have loose sediment, the activities in which people participate on these rocky shore platforms are the same as those taking place on the sandy beaches. Most of the activities that impact these areas are also similar. As such, both rocky platforms and sand beaches will be treated as beaches for the sake of simplification. Beaches on Malta are utilized 24 hours a day during summer months for a number of activities including swimming, snorkeling, sunbathing, sport, relaxation, photography, and barbeques and picnics (Zarb, 2011). Beaches are used year round, though visitation is significantly higher in the spring and summer months (Garcia & Servera, 2003; Mangion, 2001). During summer months, 85% of tourists use the beaches at least once, and resident use is high as well (Mangion, 2001). Summer densities on Malta are 7m^2 per person on sandy beaches and 10 m^2 per person on rocky beaches, though Gozo has lower densities overall (Mangion, 2001). The beaches are above the saturation point though densities are similar to those on beaches in Mallorca (Garcia & Servera, 2003).

The Tourism Policy for the Maltese Islands proposes increased investment in beach facilities and management in an effort to qualify beaches for blue flag status (Ministry of Tourism and Culture, 2007). The blue flag program is an "eco-labeling program" sponsored by the Foundation for Environmental Education that requires beaches to meet certain criteria before qualifying. These criteria include educational signage, water quality standards, management guidelines, and safety requirements (Foundation for Environmental Education). Malta currently has two beaches that qualify: the Bugibba Perched Beach and St Georges Beach in St Julian's. Both of these beaches have been significantly altered from their natural state (Foundation for Environmental Education). St George's beach underwent sand replenishment in 2005 to enlarge the eroding natural beach. The perched beach in Bugibba is actually a rocky

beach that was transformed into a sandy beach in 2006 (Foundation for Environmental Education). The tourism plan seeks to create more of these artificial beaches in the future to reduce visitors to natural beaches (Ministry of Tourism and Culture, 2007).

The main threats to tourism on beaches and the beach ecosystem result from overuse, and litter production. High densities of beach use are a problem for multiple reasons. Overcrowding decreases tourist satisfaction and enjoyment, which in turn decreases financial returns of the tourism industry (Mangion, 2001; Micallef & Williams, 2002). Substantial masses of people also exacerbate existing issues of litter production and disposal and resource use. Infralittoral and dunal habitats are also extremely sensitive to trampling and debris (L. F. Cassar & Stevens, 2002; Milazzo et al., 2002). Trampled areas show lower biodiversity, species density, and habitat complexity when compared to non-trampled areas (Milazzo et al., 2002). This lowers the habitat quality for the production of other ecosystem services.

Litter is also a significant problem on Malta's beaches. Litter is visually unpleasant to beachgoers, and a potential safety hazard to humans, animals, and the marine environment. Issues with substantial amounts of litter could significantly decrease tourism profits if tourists choose to go elsewhere. In a 1999 survey, more than half of tourist respondents though that Malta was dirty (Pollacco, 2003). Litter on the beaches can be delivered by land-based sources or sea-based sources. Using principal components analysis, Tudor *et al* were able to determine that the majority of debris found on Malta's beaches was generated by the beach user. Cigarette butts, plastic bottles, and take-away containers were found in high numbers (Tudor, Williams, Randerson, Ergin, & Earll, 2002). This indicates either a lack of disposal facilities or significant apathy on the part of the beach users themselves. The government is trying to reduce the litter by daily beach cleaning during the summer on some beaches and increasing trash and recycling receptacles (Ministry of Tourism and Culture, 2007).

2.4.3 Scuba Diving:

Scuba diving is an important attraction for the tourism industry on Malta. The island supports 46 dive operators, 34 on Malta and 12 on Gozo (Ministry of Tourism and Culture, 2007). People participate in recreational scuba diving because they have an interest in marine ecology, in particular underwater features (like statues or wrecks) or species (like sharks or coral), or in pursuit of hobbies such as underwater photography. They may regard it as a risky adventure, a unique sport, or they may have a general interest in wild environments (Davis & Tisdell, 1995). Malta is seen as a particularly good place for scuba diving as it has good visibility, a diversity of dive sites including many wrecks and caves, and the availability of shore activities (Lemon, 2008). The government has identified diving tourists as a target group and made an effort to make Malta more attractive to this group (Ministry of Tourism and Culture, 2007). In this vein, the government has attempted to increase access, security, information, and safety at dive sites, scuttle boats to provide additional attractions for divers, outlawed fishing on several wrecks, and successfully eliminated the dumping of raw sewage into the sea (Ministry of Tourism and Culture, 2007). Malta has more than 45 identified and regularly dived sites, but the submarine landscape is suitable for diving along the entire coastline.

Major threats to diving in Malta include increasing prices, nutrient loading from fish farms, over saturation of dive sites, deteriorating ecosystems and damage by scuba divers. Because extremely good visibility is one of the characteristics of Malta's diving sites, sustained decreases in water clarity will have a negative effect on the number of visitors coming to dive. Aquaculture facilities decrease water clarity because of the high concentrations of feed, organic matter and fecal material in a small area (Holmer, Hansen, Karakassis, Borg, & Schembri, 2008; Pergent-Martini, Boudouresque, Pasqualini, & Pergent, 2006). While aquaculture may offer the possibility of a 'specialty dive,' large numbers of cages close to the coast will eventually decrease water clarity nearby. Aquaculture farms also have been shown to decrease biodiversity and

damage ecosystems. Proper siting and limiting the number of these facilities is a relatively easy way to maintain the high level of visibility that divers are accustomed to on Malta.

Overcrowding of dive sites is a serious problem because of decreased satisfaction as sites no longer feel 'wild', as well as cumulative impacts of the divers themselves. Divers themselves also are capable of damaging the marine ecosystems that they visit. While the impacts individually may be small and for a short time, the cumulative effects of large numbers of divers visiting these sites may be significant (Davis & Tisdell, 1995; Dearden, Bennett, & Rollins, 2007; 2007; Luna et al., 2009). One of the effects of scuttling boats specifically for divers is that it serves to concentrate divers that previously used several widespread sites in one area (Bellan & Bellan-Santini, 2001). This can have the effect of creating dive sites that are under high levels of stress, decreasing visitation at other areas, allowing these less frequented sites time to recover. Risk assessments of the long-term damage that divers can do to a site should be based on the rates of damage and a timeline for repairing the damage (Di Franco, Milazzo, Baiata, Tomasello, & Chemello, 2009). Scuba diving can be a driving force for underwater habitat conservation as well as degradation (Dearden et al., 2007; 2007). Divers themselves often are actively involved in efforts to preserve these habitats and the money they spend can be an economic incentive to protect these areas. Degradation occurs when divers and boats overuse and damage the environment.

Most ecosystem damages arise from divers making physical contact with the environment. This can result in removal of algae, damages to hard sessile invertebrates, removal of organisms, trampling and sediment suspension (Davis & Tisdell, 1995; Dearden et al., 2007; 2007; Di Franco et al., 2009; Luna et al., 2009). Most of this damage occurs from poor buoyancy and lack of skills resulting in divers encountering the environment via their equipment, fins, and occasionally hands (Davis & Tisdell, 1995; Luna et al., 2009). Luna *et al*

found that 96% of divers made at least one contact with the seabed during a 45 minute dive, with an average of 41 contacts in a 10 minute period (Luna et al., 2009). Additional issues are harassment of charismatic megafauna such as octopuses, and air bubbles becoming trapped in marine caves where they can destroy the life there (Di Franco et al., 2009). Coral Cave in Gozo is particularly susceptible to this issue. The good news about this is that multiple studies have shown that an educational briefing emphasizing buoyancy control and diver behavior is effective at reducing these problems (Di Franco et al., 2009; Luna et al., 2009). Additional policies such as limiting particularly sensitive habitats to divers that are experienced may also serve to protect these sites from first time or lapsed divers (Di Franco et al., 2009).

2.4.4 Boating

As Malta is an island, recreational boating and yachting are popular activities. A number of large marinas and harbours where enthusiasts can berth their crafts exist. In 1996, Malta opened its docks up to the cruise industry (Mangion, 2001). Boating is popular as a means to support diving and recreational fishing, as a way to access remote places, as a sport or adrenaline rush, and as a fun activity. It does not require a particular habitat, needing only the water's surface. Trash and pollution can decrease the attractiveness of the activity. However boating itself can have a substantial impact on the environment. Marinas, piers, breakwaters, deep water docks for cruise ships and other infrastructure developments cause changes to natural circulation, and increased sedimentation while they are being built (Hall, 2001; Milazzo et al., 2002; Orth et al., 2006). These structures can also destroy habitats by shading and concretization. In addition to developments and structures to support boating, the act of boating can also cause damage to the environment.

The three main environmental impacts that boating have are benthic disturbances, pollution, and animal stress. Anchoring can cause damage to rocky reefs by breaking the rocks,

decreasing complexity, or removing attached plant and animal life (Hall, 2001). On seagrass beds, anchors can damage and pull up the root systems, directly affecting meadow cover and shoot density (Milazzo et al., 2002). Anchors can also land on sensitive and sessile life, resulting in death or damage (Hall, 2001). However, the impacts extend beyond the point of impact as long anchor chains bounce in the waves and anchors can drag as the boat shifts with the wind (Burgin & Hardiman, 2011). Mooring buoys are often placed at popular sites to prevent this from happening. Shallow areas, boat ramps, and marinas are also susceptible to scars and sediment erosion from frequent propeller turbulence.

Fuel and toxins from antifouling paints are the most substantial contributors to boating pollution (Burgin & Hardiman, 2011). Small fuel spills happen when people are fueling and switching tanks. These small spills reduce water quality, which in turn reduces photosynthesis rates and can smother flora (Orth et al., 2006). There are a number of antifouling paints that end up polluting the marine environment. Painted onto boats to prevent encrusting organisms from growing on boat hulls, these paints often are composed of heavy metals which can bioaccumulate up the marine food chain, or accumulate in sediments (Burgin & Hardiman, 2011). One of the worst of these chemicals is tributyltin, commonly known as TBT (Malta Environment and Planning Authority, 2007) (Burgin & Hardiman, 2011). In addition, TBT is toxic to a number of organisms including those that do not attach to hulls (Burgin & Hardiman, 2011). It is known to cause imposex in gastropods, a condition where female snails show male sexual characteristics, decreasing reproductive rates and causing population declines and in some cases local extinction (Burgin & Hardiman, 2011; Malta Environment and Planning Authority, 2007). TBT was banned by the International Maritime Organization in 2008 but because of its slow rate of degradation and the bio and sediment accumulation, areas are expected to still be affected by it more than ten years after it has been eliminated (Burgin & Hardiman, 2011). In a 2006 survey, TBT was found in marine sediments off of Qarraba at ten

times the ecologically safe level, likely due to high maritime traffic (Malta Environment and Planning Authority, 2007).

Large volumes of maritime traffic also can combine to create problems for local marine fauna (Bickel, Hammond, & Tang, 2011; Burgin & Hardiman, 2011). Noise pollution from motorized boats can cause stress, reduced reproduction rates, behavioral changes and localized emigration (Burgin & Hardiman, 2011). Leaving areas of prime habitat can result in decreased survivorship if animals are in a vulnerable stage (Burgin & Hardiman, 2011). Excessive turbulence from propellers also has been shown to detrimentally impact plankton populations. The sudden changes of environmental characteristics and increase in turbulence have been shown to alter planktonic trophic interactions and negatively affect bodily functions (Bickel et al., 2011). Turbulence in boat wakes is stronger than regular turbulence and the presence of dead carcasses within the wake indicates that areas with large volumes of boat traffic may have a less productive planktonic community (Bickel et al., 2011). This could affect the trophic structure of communities near the entrances to popular harbors, boat ramps, and marinas.

The intensity of use and oversaturation is a significant contributor to environmental impacts for all of these activities. Activity-specific carrying capacities could be established to maintain ecosystem integrity but the issue lies in how to enforce and encourage reductions in numbers without destroying the industries themselves, especially given the open access nature of marine environments and the Maltese penchant for ignoring regulations. The MTA seems to focus on increasing facilities and tourism arrivals despite the potential environmental impacts of these actions. Tourism efforts promote climate, sun, warmth, and sand, but the industry's dependency on the environment is not understood by those involved. The literature produced by the industry focuses on how they are meeting legal obligations for environmental protection

rather than on the dependency of tourism on high quality environments and solutions for protecting these environments (Pollacco, 2003).

3. Methodology:

3.1 Description of the Study Area

Malta is an island nation located in the center of the Mediterranean Sea along the Strait of Sicily that divides the Mediterranean into two basins. It is comprised of three inhabited islands, Malta, Gozo, and Comino, as well as several uninhabited islands. The total area of the islands amounts to 316 km^2 with approximately 253 km of coastline (National Statistics Office, 2010; Schembri et al., 2005). Malta has a high population density, with most of its 412,970 inhabitants speaking both English and Maltese (National Statistics Office, 2010). This number is further increased by the influx of 1.2-1.3 million tourists that visit Malta each year (Said; Schembri et al., 2005). Tourism and shipping are major components of the Maltese economy and both rely heavily on Malta's marine environment. Currently Malta ranks fourth in the world for the number of registered commercial vessels with 1571 vessels registered in 2010(USA Central Intelligence Agency, 2011). There are several environmental issues of concern on Malta related to the low availability of natural resources combined with a high population density. Issues include lack of space resulting in competition between land uses especially in coastal areas, reliance on desalinization plants for fresh water and importation of foreign oil and natural gas for energy needs (Malta Environment and Planning Authority, 2002).

The Maltese Islands are composed mostly of sedimentary limestone and clays (Malta Environment and Planning Authority, 2002; Schembri et al., 2005). The coastline is highly influenced by oceanic geomorphological processes, with sharp cliffs, caves, crevices, arches, stacks and stumps being fairly common. The rocky shore contains a number of small bays that contain coarsely grained pocket beaches. These sandy beaches make up less than 2% of the coastline of the Maltese Islands (Malta Environment and Planning Authority, 2002; Schembri et al., 2005). Larger bays have been converted into ports to handle the large numbers of shipping containers, cruise ships, private yachts, and larger vessels that visit the islands. The

two largest ports are located on the island of Malta at Marsaxlokk and the Valletta Grand Harbor. These and other built up areas comprise about 7% of the coastline, though if only accessible areas are considered, the ratio increases dramatically (Schembri et al., 2005).

Both Malta and Gozo have an elevation that is much higher on the southwest side of the island, making it dominated by cliffs and largely inaccessible (Schembri et al., 2005). Lower elevations allow easier access to the sea on the northeastern part of the islands (Malta Environment and Planning Authority, 2002; Schembri et al., 2005). On Malta, this influenced the pattern of settlement, with most of the coastal development located on the northeastern side of the island (Schembri et al., 2005). The Maltese Islands are mostly tideless, though the winds can push water into bays causing strong currents, waves and changes in water depth (Lemon, 2008; Schembri et al., 2005). The islands' location at the dividing point between the two basins means that there is not a substantial nutrient load added to the waters. This allows the waters around Malta to be relatively clear and it is normal to have visibility of up to 30 meters or more (Lemon, 2008).

Below the water surface, there are five primary assemblages: well-sorted sandy bottoms, beds of maerl, rocky macro algal communities, seagrass beds, and underwater caves (Malta Environment and Planning Authority, 2002). These communities show variability and subtypes due to factors such as light intensity, bottom type, wave action, and anthropogenic influences. Sea grass beds are characterized by *Posidonia oceanica* in deeper, more active waters and *Cymodocea nodosa* in more sheltered shallower waters. These seagrass beds are highly productive and provide food structure and hiding places for marine organisms. It is thought that these meadows are a nursery ground for important local seafood species (Malta Environment and Planning Authority, 2002). *Posidonia oceanica* beds are protected as a priority habitat under the EU Habitats directive as well as under the Maltese Environment and

Development Planning Act (Cap 504) through Legal Notice 311 of 2006 (European Union, 1992 updated 2007; Malta Environment and Planning Authority, 2006). Overall the rocky algal communities are dominated by species of *Cytoseira* in both deep and shallow waters (Malta Environment and Planning Authority, 2002; Schembri et al., 2005). There is however a great deal of heterogeneity in the species assemblages between microhabitats due to light penetration, exposure, hydrographic conditions and the nature of the substratum (Malta Environment and Planning Authority, 2002; Schembri et al., 2005). These photophyllic algae communities have high abundance and species richness (Schembri et al., 2005). Maerl beds are found primarily off the northern and northwestern coasts in slightly deeper waters. Maerl assemblages form when coralline algal species begin to grow on coarse substrata (J. A. Borg, Howege, Lanfranco, Micallef, & Mifsud, C. & Schembri, P.J., 1998; Malta Environment and Planning Authority, 2002). These assemblages create twig-like and encrusting formations that add additional structure to an otherwise unstructured area, making it more favorable for life and increasing biodiversity (J. A. Borg et al., 1998). The common species in Maltese waters are *Phymatlithon calcareum*, *Lithothamnion minervae*, and *Lithothamnion coralloides* (J. A. Borg et al., 1998; Malta Environment and Planning Authority, 2002). These sand communities have a much lower productivity due to the highly dynamic environment, resulting in a lack of available structure. The lack of structure means less area for hiding and fewer food resources available (P. Guidetti, 2000a). Organisms found in this habitat tend to be bivalves and polychaetes (J. A. Borg & Schembri P.J., 2002). Submerged caves are characterized by primarily sessile organisms such as coralline algaes, sponges, non-photophyllic corals, tubeworms and bryozoans (J. A. Borg & Schembri P.J., 2002; Malta Environment and Planning Authority, 2002). These caves show large variations in the type of species found between cave openings and areas deep inside the cave (J. A. Borg & Schembri P.J., 2002; S. Bussotti & Guidetti, 2009). Though many species may prefer a particular habitat during each stage of its life, most Mediterranean coastal fish use a mosaic of connected habitats over their lifetimes (S. Bussotti & Guidetti, 2010).

As this study also includes coastal terrestrial services, the terrestrial habitats found on Malta are also significant. While there are a number of definitions for coastal zones, some of which might include the entire islands of Malta, Gozo, and Comino, only those habitats directly related to this study will be described here. These include sand dunes and sandy beaches, gently sloping rocky shores and human developed areas. As was mentioned above, sand beaches represent less than 2% of the Maltese coastline, but are heavily used by residents and tourists for recreational purposes during the summer months (Malta Environment and Planning Authority, 2002). During the winter months, banquettes of dead seagrass are allowed to accumulate and provide habitat for a range of invertebrates (J. A. Borg & Schembri P.J., 2002). Dune systems are even more rare; only Ramla Bay on Gozo supports a complete dune system, though partial dune systems are present at four other sites across the islands (Malta Environment and Planning Authority, 2002). These systems have lost much of their flora and the ecosystem is considered one of the rarest on the island (L. F. Cassar & Stevens, 2002). The gently sloping rocky shores on Malta tend to be made of coralline or globigerina limestone. As these shores have eroded, the coralline shores tended to become karstic, while globigerina shores tend to be smooth (Malta Environment and Planning Authority, 2002). Both types show evidence of human modification in many of the frequently accessed areas.

As an island nation, the marine environment around Malta is heavily used. Major activities include recreation, fishing, shipping, bunkering, and aquaculture. These activities can be in competition with each other resulting in disputes over the best use of the marine space (Malta Fisheries Department, 2006). Malta currently has five marine protected areas established by MEPA; however regulations within these areas are almost nonexistent (Cousin). Malta already has issues with a lack of resources to manage terrestrial environments. It is not surprising then that with the additional difficulties of enforcing and managing marine resources

that there are few regulations within these MPAs. The few areas around the islands where fishing is restricted are set up through Transport Malta rather than through MEPA.

With Malta's accession into the European Union (EU), a 25 nautical mile (Nmi) Fisheries Management Zone was established from what had previously been territorial waters (Sant, 2007). On paper, the FMZ limits the boat size, number of boats and nationality of fishing boats within the 25 Nmi zone. Trawling, lampuki fishing, lampara fishing, and fishing for migratory species (such as tuna and swordfish) are allowed in the FMZ (Darmanin & Dimech, 2007). Evaluations of the ecosystem services provided by the marine environment combined with a valuation scheme and spatial description of the areas of use could be useful in determining the best locations for each of these activities and provide a framework for resolving disputes.

3.2 Stakeholder Surveys

Solving global environmental problems will only be possible with a concerted effort from scientists, managers, engineers, policy makers, business leaders and the general public together. Given the importance of ecosystem services to human well-being and the Maltese economy, it is important for these stakeholders to understand the situation. But how much do people really know about ecosystem services? And how much do they care about them? Do they understand how their actions can impact the delivery of these services? To answer these questions, three different surveys were developed and distributed to three different stakeholder groups in Malta: scuba divers, tourists, and residents. The aim of these surveys was to develop an understanding of the activities that these groups participate in, their comprehension and understanding of the ecosystem services concept, as well as their impacts on the marine environment and their perception of the worth of the services that marine ecosystems around Malta provide.

3.2.1 – Resident Surveys

It was determined that the most efficient way to survey a large number of residents would be to use an internet survey with a snowball distribution as the primary researcher had restricted time and funding with which to complete the data collection as well as limited acquaintances as a non-resident. Internet surveys have the benefits of quick response time, low cost, and immediate data input (Sexton, Miller, & Dietsch, 2011; Wherrett, 1999; K. B. Wright, 2005; Zhang, 2000). Internet surveying also allows responses from any computer, so multiple respondents can take the survey at the same time, and the population does not need to be captured in a specific area. It is also possible to introduce flexibility into the survey questions so that respondents can have a survey designed for them (Sexton et al., 2011; Wherrett, 1999; K. B. Wright, 2005; Zhang, 2000). The resident survey was designed and implemented online using the survey design software provided by SurveyGizmo and included several of these flexible measures (*Survey gizmo 3.0*. 2011). It is possible to view the entire survey in Appendix B. For example, respondents were asked if they participated in a number of activities. For those activities in which the respondent had participated, follow up questions about frequency would appear. This reduced the number of questions, and allowed those who had not participated in a particular activity to ignore the questions associated with that activity.

Internet surveys have been criticized for skewing population samples. This survey was aimed at surveying the population of Maltese residents; however, any internet survey is only capable of reaching those members of a population who have access to the Internet, effectively removing those residents without Internet access from the sample (Conrad, Christie, & Fazey, 2011; Sexton et al., 2011; Wherrett, 1999; Zhang, 2000). This is not hugely limiting in Malta, as in 2010, 78% of individuals between the ages of 16 and 74 in Malta had access to a computer with Internet at home, including 96% of households containing 2 adults and children(National Statistics Office, 2011). This is higher than the EU average (Seybert & Loof, 2010). Other

commonly cited problems with internet surveying are issues of poll crashing and misrepresentation of respondents (Conrad et al., 2011; Sexton et al., 2011; Zhang, 2000). These issues were not addressed in the survey design.

The choice of a snowball distribution pattern brought a few significant biases to the survey design. Snowball sampling uses social networks to find a pool of respondents. In this case, the primary researcher asked all of her contacts to take the survey and then ask all of their contacts to take the survey and so on. When there is no database of the population from which to randomly sample, snowball sampling allows a large number of people to be contacted in a short period of time, as well as lending a degree of personalization to the survey request. It has been shown that impersonal communications result in low survey response rates, so having survey requests come from an acquaintance makes it more likely someone will respond (Zhang, 2000). Because social networks are comprised of people who have something in common, to strive for true representativeness, the origin of the snowballs is important (Browne, 2005). A large bias is therefore introduced by the circumstance where a majority of the primary researcher's contacts (and thus the beginning of the snowballs) are through conservation-oriented organizations and programs. With limited time and funding and no national database of e-mail addresses, it was determined that introducing the bias was worth the benefits that snowball sampling allowed. Effort was made to minimize these effects by using the Facebook social networking site to try to recruit from a larger population.

The resident survey questions began by asking about the occurrence and frequency of respondent participation in a number of marine recreational activities. The survey then asked about familiarity with the ecosystem service term. Respondents were asked about the importance of and impacts on the specific three ecosystem services chosen for this study. A full copy of the survey is shown in Appendix B.

3.2.2 – Tourist Surveys

Surveying tourists is critical as tourists are important stakeholders and recreational user of the marine environment. The process of surveying tourists is more difficult, as they are a transient population with few unifying characteristics. Tourists on Malta arrive by boat or plane; they stay in apartments, with families, at language schools and hotels (Ellul, 2011). There are certain areas where tourists congregate and these were targeted. Areas such as St Julian's and Bugibba are the primary areas where tourists stay (Mangion, 2001). Valletta as the capital city and Cirkewwa as the gateway to Gozo are also areas with significant numbers of tourists. A one page survey was developed and distributed by the primary researcher on clipboards to tourists following a brief introduction to the purpose of the study and assurance that they were indeed a tourist. Tourists then read and responded to the survey without the interference of the primary researcher. Several locations were used including: The Park Hotel, Sliema; The Westin Dragonara Hotel, St Julian's; Palace Square, Valletta; the Malta Airport, Luqa; Marsalforn, Gozo; the Gozo Ferry and Misrah il Bajja in Bugibba. The surveys were written in English, and it was not anticipated that requiring respondents to speak English would be a problem as English is one of the two national languages, and many people come to Malta to learn and improve their English skills. However, a number of tourists that declined to take the survey responded that they do not speak English. This may have skewed the sample towards respondents who are native English speakers, as well as non-native speakers with a higher education. While the resident survey focused more on valuation and the ecosystem service concept, tourist surveys focused on their perception of the environmental impact they are having as a tourist. A full copy of the survey can be found in Appendix B.

3.2.3 Scuba Diver Surveys

As a primary user and one of the few stakeholders to see the entire marine environment, divers have a unique perspective. Diving is one of the major recreational activities on Malta and as such, divers' ecosystem preferences and opinions are a factor in determining what

environments are important for recreation and tourism, and tracking changes to ecosystem health. The diver surveys were handed out to certified divers by several dive shops across the island: Selkies in Sliema, Neptune's in St Julian's, New Dimensions Scuba and Strand Diving in St Paul's Bay. Additional surveys were distributed by the primary researcher as she interacted with scuba divers herself as well as through e-mail to members of the Amphibians Dive Club.

The diver survey sought to determine the most favored habitats, factors influencing the decision to dive, knowledge of local conditions and changes to those conditions, as well as if they recognized the potential impacts that diving can have on the environment. A full copy of the survey can be found in Appendix B.

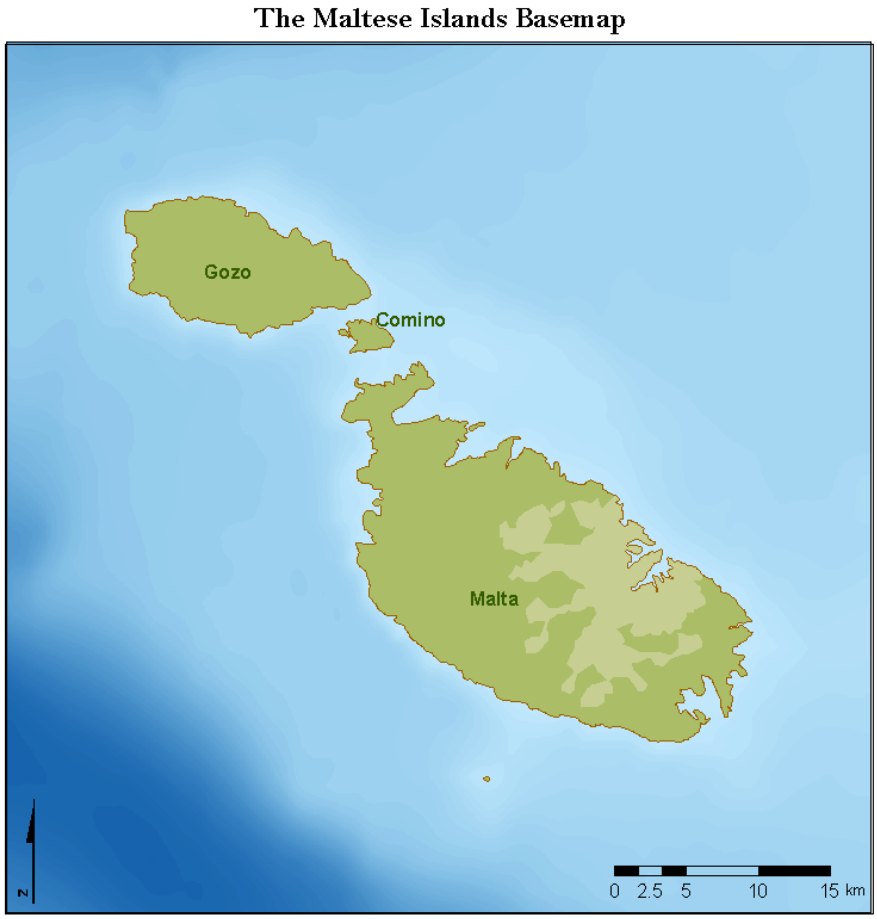
3.3 GIS Mapping of Impacts and Ecosystems:

Ecosystem services have important spatial components, and as such, a Geographic Information System (GIS) can be a valuable tool for visualizing data and assisting in the planning process. GIS allows quantitative data such as salinity or depth and qualitative data such as type of habitat to be tied to a place. This allows multiple datasets to be organized, integrated, and analyzed spatially. These new maps can increase understanding and help managers as they make critical decisions. GIS has been an especially helpful tool for the oceans and coasts, where it can be hard to mentally visualize biological, chemical, physical, geological, and social data (D. Wright, 2011). GIS is currently being used by the Ecosystem-Based Management Tools Network for assistance in baseline studies, stakeholder engagement, decision support, monitoring and modeling processes (D. Wright, 2011).

For this section, research of current literature and interviews with experts and stakeholders were conducted to determine the marine habitats that were important for providing each of the selected three ecosystem services. Each ecosystem service had specific

areas and habitats that were essential to ensure the delivery of these services. Following the identification of these particular areas and habitats, data about where these habitats might exist were sought. MEPA does not have extensive habitat specific maps for the Maltese coastline, and as such only 13 areas could be identified to habitat level. Research also was conducted to identify activities that might influence such services and where these activities take place around Malta. Data were collected from a variety of sources that are listed in Appendix D at the end of this work. ESRI's ArcMap 9.3.1 software was used to map and analyze the data collected. Data were rarely in shapefile form so most of the shapefiles were created by the primary researcher from maps and latitude and longitude points. New maps were created where data about habitats and essential area were overlaid with the impacts and use data. These maps allow comparisons to be made between areas that are important for the continuation of the ecosystem service and areas of activities that may degrade such services. Points of possible conflict were identified and then used as discussion topics.

The base map used for this project is shown in Map 1.0 on the following page. The map covers Malta's territorial waters. Bathymetric data from the NOAA Geophysical Data System is shown in blue with greater depths shown in darker shades. Malta's urban areas are shown in grey. This map will be used as the base for the other layers of information. Each of the three ecosystem services has different activities and areas of importance that can be shown. Layered on top of these areas of importance for the ecosystem service are areas of activities that can affect the delivery of the service. A complete list of the different layers can be found in Appendix D.



Map 1.0: Base map of the Maltese Islands

4. Results:

4.1 Surveys

In total 385 surveys were partially or fully completed. The response rate is unknown as the nature of the snowball survey design does not allow the researchers to know how many people saw, but declined to take the survey. The number of people declining to take the survey in person was not counted. The categorical data were examined using the Two-Sample χ^2 Test for homogeneity. The null hypothesis for these tests was that there is no difference between the responses of each group. The null hypothesis was tested at $\alpha = 0.05$. Groups tested were tourist or resident, age, gender, and profession. Tests were not run based on nationality due to the small size of several groups. Descriptive data were tallied and examined for trends and common responses. Means and standard deviations were calculated for ranked data sets

Stakeholder Category	Sample Size	Gender Distribution		Age Distribution		Profession	
Residents	n = 188	Males	69	18 - 24	40	Education	11
		Females	79	25 - 34	59	Other	10
		Unspecified	40	35 - 55	42	Policy	22
				55 +	9	Professional	49
				Unspecified	38	Scientific	33
						Student	16
						Tourism	8
						Unspecified	39
Tourists	n = 143	Males	68	18 - 24	18	Education	18
		Females	73	25 - 35	36	Other	12
		Unspecified	2	36 - 50	43	Policy	5
				51 - 65	40	Professional	66
				65 +	4	Retired	7
				Unspecified	2	Scientific	8
						Student	18
						Unspecified	9
Divers	n = 54	Males	40	18 - 24	7	Diving	14
		Females	14	25 - 35	14	Non Diving	37
				36 - 50	23	Unspecified	3
				51 - 65	10		

Table 2: Summary of respondent demographics used for analysis

4.1.2 Resident Surveys

4.1.2.a Respondent Profile

220 people began to take the resident survey. Of these, 188 completed at least part of the survey and 150 reached the last screen. People who partially completed the survey but did not respond to the first question about activities they participate in were assumed to have decided not to take the survey as not a single person responded to any of the further questions after not picking any activities that they participated in. The answers of those who did not complete the survey were used until they stopped answering questions, at which point they were no longer counted. Most of these partial responders did not complete demographic questions and as such, their answers were not included in the demographic analysis, though they may have been included in the overall analysis.

Of the 150 respondents who completed the survey, 53% were female and 46% male. This ratio is not significantly different from the 2009 resident population ($\chi^2 = 0.43$, $p = 0.51$) (National Statistics Office, 2010). Age data were taken in groups, the smallest group being those greater than 55 years of age at 6% of respondents. This was not entirely unexpected as older segments of the population often do not have the computer skills and online social network that younger generations have. The other three age ranges were similarly represented, with 18 – 24 year olds comprising 27% of the sample, 25 – 34 year olds comprising 39% of the sample and 35 – 54 year olds representing 28% of respondents. It is likely that the data were biased towards younger groups as the author's primary contacts were in the younger age ranges and people's social networks tend to be comprised of similar types.

There were seven nationalities represented, though often residents stating 'other' identified as Maltese and another nationality. They were counted as representing the non-Maltese nationality. Survey respondents were overwhelmingly Maltese (91%), with British and American each comprising 3% of the sample, and German, Swedish, Australian and Canadian

each representing less than 1% of the sample. The large proportion of Maltese is reflected again in the time period lived in Malta. 93% of respondents stated that they had lived in Malta for more than 10 years. Each of the three other categories (i.e. less than 1 year, 1-5 years, and 5-10 years) was represented by 2% of the sample.

The answers to the question "what is your profession" varied widely. A large portion of the responses, 32% picked other as the category for their profession. From the descriptions of these other professions, additional categories were created. Those who marked other as their profession were then placed in a category based on where they were thought to fit best. Those who listed professions in business were placed in the professional category. Those in the media were thought to fit into the policy making category, as they help to frame and shape the debate about these topics in the public arena. A separate category was created for those in education professions. Those working in restaurants and hotels were categorized as tourism. Following reclassification, the groups were identified as 7% Education, 7% Other, 15% Policy, 33% Professional, 22% Science, 11% Student, and 5% Tourism.

Interestingly, the software was able to identify at least 35 people who connected to the survey through the social networking site Facebook. Had the request for respondents been placed in more pages on the site, it is highly probable that there would have been more hits. Facebook should now be assumed to be a viable way to recruit survey respondents.

4.1.2.b Activities

100% of respondents participated in at least one of the activities listed. Malta's status as a group of islands means that the country is largely dependant on the sea to provide people with access to the rest of the world. Only 4 out of the 14 activities did not have at least 50% of respondents saying they had participated in them. Swimming was by far the most popular activity that residents participated in; 93% said they had been swimming from a rock beach, and

92% reported swimming from a sand beach. This is primarily a summer activity, with less than 10% saying they swam year round. Other popular activities were eating seafood (84%), barbequing (81% on rock beaches, 75% on sand beaches) and sunbathing (79%). The least common activity was commercial fishing (3%); all of those who reported commercial fishing stated that they participated 1-2 times a year or less. Clearly, these men are not making their living solely from fishing if they are only fishing 1-2 times per year. The percentages of those participating in other activities are shown in Figure 2 below. The "Other" option allowed participants to write in their own marine-based activity. There were several write in activities that had not been included in the survey; of these, sport was perhaps the most popular. Other suggestions were walking, photography, education, research, camping, and beach cleanups.

Most of the activities were listed as summertime activities. Only two activities, scuba diving, and recreational fishing from shore had more than 40% of those who participated saying

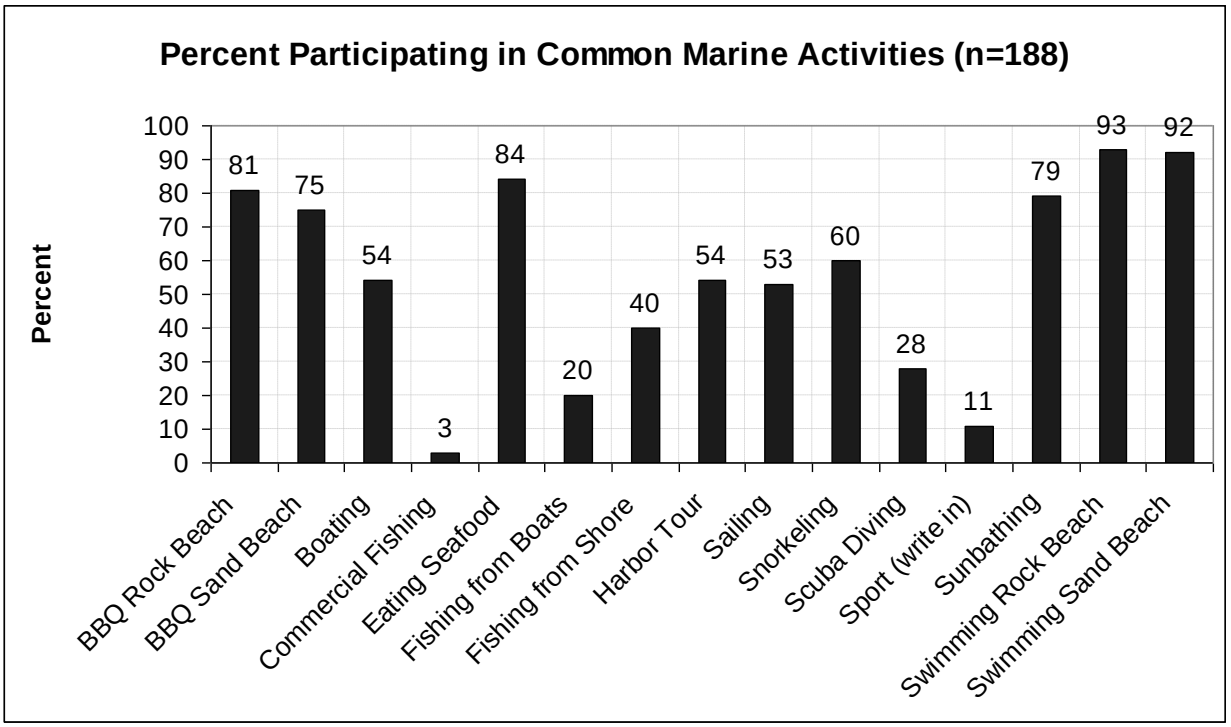


Figure 2: Percent of respondents participating in common marine activities, Write in indicates that this was not a preset choice

they participated year round. Only four activities had more than 10% of respondents choosing the year round option, adding boating and recreational fishing from a boat. Although no timeframe was asked for those who eat seafood, 61% of those who selected eating seafood as an activity eat it once a week or more.

For the demographic analysis, men were more likely to participate in scuba diving (χ^2 = 3.91, p = 0.047), snorkeling (χ^2 = 5.83, p = 0.016) and all three types of fishing ($\chi^2_{commercial}$ = 4.71, p = 0.030; $\chi^2_{from\ shore}$ = 4.09, p = 0.043; $\chi^2_{from\ boat}$ = 8.54, p = 0.003). Women were more likely to sunbathe (χ^2 = 7.24, p = 0.007). The greater participation of men in scuba follows the estimates of skin diver magazine (Davis & Tisdell, 1995). Sunbathers were also more likely to be in the younger two age groups (χ^2 = 12.08, p = 0.007). Respondents in the 35 – 54 age bracket were less likely to barbeque when compared to other groups ($\chi^2_{on\ rocks}$ = 11.01, p = 0.012; $\chi^2_{on\ sand}$ = 9.82, p = 0.02). Profession did not have a major role in activities people participate in, though the scientific community is more likely to participate in recreational fishing from a boat (χ^2 = 18.06, p = 0.006), and those in education are less likely to barbeque than the other groups (χ^2 = 15.47, p = 0.017).

The data show that the Maltese are heavily involved in recreational activities that are tied to the sea. Interestingly, the one non-recreational activity that was asked about, commercial fishing was the activity that the fewest number of people participated in. While the data may be skewed by who was asked to take the survey, it suggests that while consuming recreation from the sea may be common, making a living from it is not. It has been suggested that this may be tied to Malta's vulnerability to marauders, corsairs and invaders throughout its history (J. A. Borg, 2011).

4.1.2.c Ecosystem Service Descriptions

There were two open-ended questions designed to gauge respondents' familiarity with the term ecosystem service. Answers from "What do you think is meant by the term, Ecosystem Service" were separated into categories established after briefly examining the data collected. These categories were given a letter code and a description of them and an example quote are shown in Table 3. Only 39% of respondents were close to a correct definition, and only 34% gave a definition that included goods *and* services. The idea that these responses truly represent what the average resident thinks is suspect also, as at least one person said they looked up the definition online after being asked, another quoted directly from the Millennium Assessment, and at least three people quoted Wikipedia word for word. Several of the answers closely reflect ideas and sentences in the first paragraph of the Ecosystem Services Wikipedia article; however it is difficult to assess whether this is because respondents looked at the article or because they had a general understanding previously. Unfortunately, the chosen method of internet surveys and the ease of looking up information facilitate this kind of plagiarism. It is unclear whether these cases reflect a desire to learn or a desire to not be wrong, even when there is nothing at stake. Being able to parrot facts from the Internet does not necessarily reflect understanding and comprehension of such a complicated topic, and policy makers and scientists should not assume that there is general understanding of the term.

17% of respondents said they did not know what ecosystem services meant. The most common incorrect answer (15%) was that an ecosystem service was a group of people charged with protecting or restoring the environment. These responses likely reflect guesses based on contextual clues. Other answers ranged from green uses for the environment to examples of services and definitions of ecosystems themselves. It is clear that there is not widespread understanding of the ecosystem services term in Malta.

Table 3: Common Definitions of Ecosystem Services given by respondents

Code	#	Percent	Definition	Example Quotes
A	55	33.7	Goods and services that nature provides to humans	*"The goods and services offered to us for free by nature."*
B	8	4.9	Goods from nature	*"Environmental resources" "Something that we get naturally, from natural systems?"*
C	28	17.1	I don't know	*"Ecosystem service?? Never heard the term." "Never heard this term. Sounds like specialised jargon, so won't hazard a guess. It wouldn't mean anything to the man in the street."*
D	11	6.7	Green or sustainable use of nature	*"I don't know. Perhaps using the environment without damaging the ecosystem." "respecting the ecosystem" "Things that keep the marine life, sea and land, safe and clean - protecting the environment"*
E	25	15.3	Humans protecting or improving the environment	*"Any form of organised activity which is related to monitoring or taking care of the ecosystem." "Probably service linked to sustainable ecosystem management." "A body that seeks to study and protect ecosystems"*
F	14	8.6	Natural maintenance of an ecosystem	*"the natural maintenance of resources." "The services an ecosystem provides for the continuation of the sustenance of the ecosystem itself (biodiversity, ecosphere etc)" "the ability of nature to recover itself after being stressed externally"*
G	7	4.3	Definition of ecosystem	*"biological environment consisting of all the organisms living in a particular area." "The term in my opinion refers to how the sea, the weather and other forces of nature work together , in that one affects the other."*
I	3	1.8	Examples of ecosystem services	*"ecosystem services include products like clean drinking water and processes such as the decomposition of wastes"*
J	12	7.4	Other	*"I believe it is the most natural form of system which collates so many bits and pieces together. It should be definitely left as natural as possible." "A specialized environment for a particular species." "How the sea functions."*

Despite the lack of understanding of the term, it is not clear that there is a lack of appreciation or knowledge that these services exist. 63% of respondents were able to list at

least one example of an ecosystem service. Examples of responses given more than once and their frequencies are listed in Table 4 by category of service. Half of the six most frequent examples given are provisioning services, emphasizing the fact that these are the services that people recognize and understand the most. The most common service to be mentioned is fresh water provisioning. It is the first example given in the Wikipedia article on ecosystem services, but the author hopes the frequency of this example reflects the scarcity of water on Malta and the resulting discussion, knowledge and applicability of the topic. Unfortunately, it is impossible to understand why this response was so frequent with the data collected. Other popular responses were food provisioning (including fish as well), pollination, recreation, and soil formation. Nine regulating services, three supporting services and three cultural services were listed by more than one respondent. This reflects a level of understanding of the 'hidden services,' at least to the point of knowledge of their existence.

Table 4: Ecosystem Service Examples

Provisioning	**Frequency**
Fresh Water	36
Food	24
Fishing	18
Sand Provisioning	6
Animals	4
Wood	3
Energy	3
Regulating	
Pollination	18
Clean Air	9
Carbon Sequestration	6
Climate Regulation	5
Chemical Filtration	3
Waste Decomposition	3
Flood Control	2
Disease Control	2
Prevent Erosion	2
Supporting	
Soil Fertility	13
Nutrient/Nitrogen Cycles	9
Nursery Habitat	3
Cultural	
Recreation	13
Landscape/Spiritual/Aesthetic	8
Education	4

Nineteen examples were given that do not fall within the scope of the definition of ecosystem services. The most common of these was some sort of environmental cleaning, reflecting the idea that ecosystem service was a term for an environmental caretaker organization. This idea was mentioned fourteen times with various iterations on the idea of

keeping beaches and waters clean. Also popular were ideas about caring for the environment (10), performing some kind of research or monitoring programs (9) and proper management of the environment including suggestions for management regulations (9).

While there may not be a complete understanding of the terminology, it appears that Maltese residents have a basic understanding of some of the goods and services nature provides to the island. This could be utilized by informed parties to provide the political will to encourage new laws protecting essential habitat and enforce laws that currently exist to do the same.

4.1.2.d Importance of selected services

Participants were asked to rank the importance of each of various ecosystem services based on a 1-5 scale. In the ranking scale, 1 was correlated to not at all important, 3 to somewhat important, and 5 to extremely important. "No opinion" and "I don't understand" were also offered as options. Averages and standard deviations were calculated. Although questions were asked about both aesthetic beauty and tourism, in later questions aesthetic beauty is considered an indicator of the health of the tourist industry as it has been established that when a place is not aesthetically pleasing, tourists cease to visit. Nursery habitats were assumed to be represented by asking questions about fishing, as the definition established earlier for nursery habitats indicates that these habitats must increase survivorship to the adult stage, when many of the species will enter the fishery.

When asked about the importance of the aesthetic beauty of the sea to Malta, answers provided a mean of 4.89 (n = 160, std dev = 0.443). This was the highest level of importance that any of the services were given. Respondents gave a mean response of 4.71 when asked to rate the importance of tourism to Malta (n = 160, std dev = 0.567). Not a single person responded with a ranking lower than three. This high ranking of importance likely reflects an

understanding of the large role tourism plays in Malta's GDP. Unfortunately the question does not ask about what role respondents thought the presence of the sea played in tourism arrivals. The role of the sea in the promotion of Malta's tourism product may be explained by tourist survey results.

The importance of fishing to Malta received the lowest importance ranking with a mean of 3.75 (n = 161, std dev = 0.915). Interestingly, despite the higher rate of men participating in fishing activities, women seemed to think that fishing was more important to Malta than men did (χ^2 = 10.80, p = 0.001). Ratings of the importance of having a predictable and consistent climate in Malta had a mean score of 4.12 (n = 158, std dev = 0.809). Demographical analyses of these data show that there is a significant difference in the rating based on profession (χ^2 = 45.4, p = 0.00). Different professions did not perceive the importance in the same way, and there seems to be no clear pattern in the responses. When asked about the importance of the sea in regulating climate, 3 people responded that they did not understand. Overall, the mean of the responses to this question was 4.21 (n = 156, std dev = 0.870). When trying to assess the importance of the sea to forming national and personal identities, people were asked to rate the importance of the sea in relation to their perception of Malta and "how you see yourself as a resident of Malta." These questions received mean scores of 4.68 and 4.40 respectively. The high level of importance attributed to the sea in relation to perception of Malta indicates that national identity is highly intertwined with the sea. The sea helps to sustain Malta, allowing travel between the islands of Malta, as well as literally connecting Malta to the outside world.

Clearly, residents of Malta perceive the marine environment to be important. Every single question received a rating higher than 3, and most of the ratings were higher than 4. Unfortunately, this may not reflect a willingness to act to protect these resources. These scores may suffer from response set bias inherent in the survey design. It is easy to say that something

is important when there are no comparisons being made. A willingness to say that something is important does not necessarily translate into favoring one service over another.

4.1.2.e Anthropogenic impacts

The next section of the survey asked participants if they felt that humans could impact the three ecosystem services. Reponses were "yes," "no," and "I don't know." If they responded yes, an open-ended question asked them to describe ways that humans could impact the specific service. It was not specified whether impacts needed to be negative or positive. 154 people answered this set of questions. When asked if humans could impact the aesthetic beauty of the sea around Malta, 96% of residents said that they could. Only 2 people said no, and 4 said they did not know. When asked to specify how, the most frequent response was dumping waste into the sea (57). Also popular were descriptions of coastal development (56) including criticisms of the number, size, legality, and style of new developments along the coast. The next most popular responses were litter on beaches (48), pollution (31), overfishing (27), and boat traffic (25). A full list of impacts that received more than 3 mentions is shown in Table 5. It is clear that litter on both beaches and in the ocean is perceived as a large problem in Malta. Respondent 248 put it quite well when they said, *"Dumping of waste in the sea can result in trash being washed up on beaches. This would make Malta's beaches less desirable for tourists and locals alike, as well as pose a threat to sensitive coastal and marine species in Malta."*

Table 5:Frequencies of Reported Human Impacts on Aesthetic Appeal

Dumping waste in the sea	57
Coastal Development/Urbanization/Construction	56
Litter on beaches (especially from BBQs)	48
Pollution	31
Fishing and Overfishing	27
Boat Traffic	25
Fish Farms	24
Overcrowding (people and boats)	22
Chemical Pollution (inc. Toxic Waste, oil etc)	21
Sewage	17
Boat Pollution	15
Changes to Flora and Fauna	10
Commercial Shipping	9
Oil Rigs and Bunkering	8
Construction Waste Disposal	7
Wind Farms	6
Discharges from Power and RO plants	5
Noise	5
Poor Drainage/Runnoff from Winter Rains	5
Erosion and Removal of Vegetation	4
Fishing Nets	4
Industry	4

When asked if humans could impact fishing in Malta, 84% said yes. Five people said humans could not impact fishing, and 18 people said that they did not know. The most popular example given for how humans could impact the environment was overfishing (48). This was followed by bad fishing practices (44), pollution (42), and dumping waste in the sea (31). The bad fishing practices answer is perhaps the most interesting of these. It is surprising that the average Maltese would know the difference between good and bad fishing practices if they were not involved in fisheries. However, several of the suggested poor practices were quite pertinent. People mentioned using nets with small mesh, catching juveniles, the industrialization of fishing, bycatch, disturbance of breeding grounds, using explosives, poor management and illegal fishing as examples. This level of understanding is promising as it means that there is already a foundational understanding to build upon to improve fisheries management. If people already understand that catching juveniles will harm populations, they might be more accepting of length restrictions. This could be useful when MEPA attempts to pass restrictions on use within Malta's MPAs. There was one response that was particularly insightful, though only 3 people even mentioned it as a pressure. Respondent 349 said, *"We consume too much as a whole. Quantities are too high and fishing cannot be sustainable. Demand for the consumption of certain fish*

Frequencies of Reported Human Impacts on Fishing		Frequencies of Reported Human Impacts on Climate	
Overfishing	48	Pollution	15
Bad Fishing Practices (Including catching juveniles, Parit nets, explosives, Open Season year-round and non-enforcement)	44	Climate Change/Global Warming	11
Pollution	42	Increasing GHG emissions	11
Dumping waste in the sea	31	Chemical Dumping	6
Fish Farms (did not say + or -)	13	Altering Sea and Wind Currents	5
Oil Spills and Bunkering	9	Disturbance of Ecosystems	5
Boat Traffic	8	Overfishing	4
Sewage Discharge	7		
Harming the Marine Ecosystem	6		
Climate Change	5		
Coastal Development	5		

Table 6: Frequencies of Reported Human Impacts on Fishing and Climate

goes beyond the possibility of ethical fishing." This response seems to take personal responsibility or the part that they play in fisheries issues. Overfishing and bad fishing practices are perceived as caused by other people if you are not a fisherman yourself, but it misses the root cause of why overfishing occurs, i.e. demand. Since 84% of those taking the survey said that they eat seafood, they too are responsible for this increased demand, even if only 3 respondents acknowledged this.

When asked if humans could impact climate, the largest proportion of people responded that they were not sure (44% of answers). Women were more likely to respond that they were unsure if humans could affect climate ($\chi^2 = 8.35$, $p = 0.015$). 39% of respondents said humans could impact climate and 16% said humans could not impact climate. Because such a large number did not answer in the affirmative, only 60 people were actually asked to describe possible anthropogenic impacts. The most common response was pollution (15), followed by global warming (11), and increasing GHG emissions (11). A number of these responses indicated uncertainty and guesses, or a generic 'global warming,' with no description of how or why this was occurring. This indicates general confusion and a lack of understanding of the problems associated with climate change by residents of Malta. Before undertaking policy actions to combat climate change and meet EU requirements it may be necessary to implement an education campaign to combat false information and misunderstandings in order to build public support.

4.1.2.f Observed Changes

The last section of the survey asked participants if they had observed changes to the selected ecosystem services. If they indicated that they had, respondents were asked to describe these changes. It is important to note that these are anecdotal and do not represent a certainty that any of these changes have actually occurred. 78% of respondents said that they had observed changes to the aesthetic beauty of Malta. The descriptions of observed changes varied widely, with 50 different changes representing both positive and negative differences, though

most tended to be negative. The most common change mentioned was an increase in coastal development (39), paralleling the response to human impacts on the aesthetics of the coast. Many of the responses were contradictory, where some people saw improvements and others thought conditions were deteriorating. The next most common responses were an increase in trash (21) and an improvement in water quality (19). Improvements in the water quality are probably related to the gradual decrease in raw sewage pumped into the sea, though as a number of people mentioned, increases in fish farms are causing decreases in water quality in areas where they are present (11). Another common theme was increases in density, whether of tourists (4), on beaches (8) or on the sea in the form of recreational (11) and commercial vessels (7). People have also noticed declines in the abundance and diversity of marine life (18). Declines in specific species such as octopus, urchins, and sea birds were also mentioned. Respondent 439 sums up the general response: *"Huge! There was a sheer abundance of fish when I was younger. Snorkeling was an amazing experience of colour and play with fish. the waterfronts have changed as well, less pristine areas, building encroachment, less rustic, noisy, polluted, too many boats (and people who are not trustworthy driving them), fuel residues from seacraft, blaring stereos. Finding a peaceful spot has become very difficult nowadays."*

Participants were also asked if they had noticed changes in the species, quantity, or size of fish and other seafood caught around Malta. 52% said that yes, they had noticed changes, 20% said no, they hadn't observed changes, and 27% said that they did not know if they had observed changes. Those who said they were unsure if they had observed changes were most likely to be in the 18 – 24 age group ($\chi^2 = 14.79$, $\alpha = 0.002$). This may indicate that changes have taken place over a longer period of time than the 18 – 24 year olds would have noticed. The most common responses are a decrease in both quantity (30) and size of fish (27). Respondent 271 gives a typical example of this type of response *"there is less fish and it's of a smaller size as well... ex up to 5yrs ago , an average tuna was circa 250kg, today its about 25-30kg, same for swordfish, from 60-80kg now down to 5-10kg."* The other 42 responses varied widely, from

declines or increases in specific species to increases in price (5) and increases in farmed (5) and imported (2) options.

The last survey question asked if respondents had observed changes in the climate of Malta. Because it was summer, it is assumed that the results may have been skewed by summertime weather events. 75% of participants said they had noticed changes, 17% said they had not noticed changes, and 8% said they were unsure. The most common changes to climate reported were: climate was warmer (69), less predictable (26), and more extreme (13). Residents mentioned that there was less precipitation (13), but when it did rain, it was violent rains and storms (10). Respondent 300 said *"This may be subjective however it feels (not scientific) that the rainy season has become shorter but more plentiful in a shorter term (i.e. monsoon effect) and temperatures have become more extreme in summer with an even shorter intermediate seasons (shorter Spring and Autumn)."* This essentially sums up the majority of comments. When comparing this question to the question can humans impact climate, 73% of people who said they did not know if humans could impact climate had witnessed changes to climate. Perhaps even more intriguing is that 74% of those who said that humans could not impact climate claimed that they have witnessed changes to climate in their lifetime. These data emphasize the confusion and misunderstanding of the climate change issues by residents in Malta.

4.1.3. Tourist Survey

4.1.3.a Demographic Profile

143 people completed the tourist survey. It is unknown how many people were asked to take the survey. The most frequent reasons given for declining to take the survey were lack of English skills and apathy. Survey responses indicated that the respondents represented 30 different countries, though 14 of these countries only had one representative. The most common nationality was British, representing 38% of the sample. Germans represented 7% of the sample. The Italians and Dutch each had 6% of the sample. The portion of British taking

the survey may have been overrepresented when compared to overall departures data. Between 2007 and 2011, the British typically represent 34% of tourist departures (Said).

There were five age categories for the tourist survey and the responses were spread fairly evenly between them. 18 – 23 year olds represented 13% of the sample, 25 – 35 year olds represented 32%. 30% of the sample was between 36 and 50 years old. 51-65 years old represented 21% of the sample, and those older than 65 represented 3% of the sample. Females were more likely to take the survey than males, representing 51% of the sample; Males represented 48%. Unlike the resident survey, tourists were asked what their profession was and they were subsequently categorized into categories similar to those from the resident survey. An additional category, Retired was added and had 5% of the sample. The largest group of people (46%) was in the professional category. Education was 13%, the scientific community had 6%, and students made up 13%. Policy making was 3% and the "other" category was 8% of the sample.

4.1.3.b Reasons for Visits to Malta

One of the goals of this study was to determine why tourists were coming to Malta and if the success of the tourist industry in Malta was dependent on the health of the marine ecosystems. Tourists were given a list of possible reasons for visiting Malta and asked to check any that applied. Space was also given if respondents wanted to write their own answers. The reasons for coming that appeared to be tied most closely to the health of marine ecosystems were the "Sun, Sea, and Sand" response, and the diving response. 65% of survey respondents said that they came to Malta for the "Sun, Sea, and Sand." This type of tourist needs to have healthy and clean beaches and waters to be happy. 10% of respondents said they came to Malta for the diving. This type of tourist seeks clear waters with large quantities of diverse wildlife.

Figure 3 shows the distribution of responses[1]. Relaxation was the answer with the second highest frequency; 63% of respondents said they came to Malta for relaxation. While not as directly linked to marine ecosystems, many people find beaches to be places of relaxation. The Sun, Sea and Sand and Relaxation responses were clearly the strongest responses. Cultural Heritage was the third most frequent answer with just 34% of respondents. Cruise stopovers (1%) and language school (4%) responses were probably underrepresented. Tourists on cruise stopovers are difficult to survey as they do not have as much time as other tourists, and are usually on some sort of tour. The St Julian's/Sliema area is where most of the language schools are concentrated; however, many of the schools have their own dorms or apartments for students to live in. It is likely that the language students are under represented because surveys in the St Julian's, Sliema area were given out in hotels. There were 16 people who answered

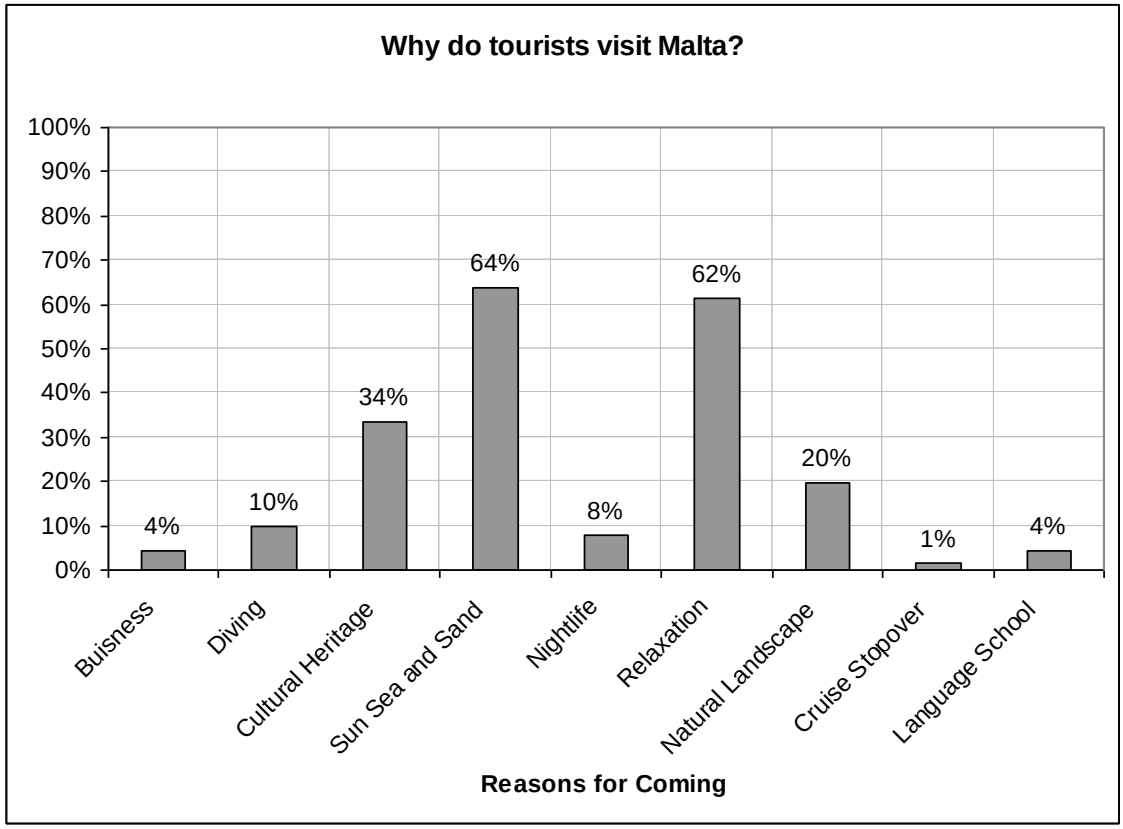


Figure 3: Tourist reasons for visiting Malta

[1] Tourists were given the option to check more than one response. Thus the sum of percentages is greater than 100.

other. Of these, the most popular reasons for coming were to visit family (7) and friends (4), having some sort of ancestral connection (3), and the low cost (2).

4.1.3.c Activities

Tourists were given a list of common activities that relate to the marine environment and asked to select all of the activities that they had participated in or were planning to participate in. The response to this question is compared with the resident's response to this question below. A summary of the tourist response is shown in Figure 4 below.

The most popular activity for tourists was sunbathing, with 77% of respondents saying they had been sunbathing. Eating seafood (55%), harbour cruises (49%), and swimming were also popular. Swimming from rock beaches (57%) was slightly more common than swimming from sand beaches (56%). This is probably due to the travel required to access sand beaches from the main tourist areas. The St Julian's/Sliema area and the Bugibba/Qawra areas have mostly rocky beaches with the exception of St Georges Bay and the perched beach. Tourists may even consider the perched beach to be a rock beach as the entrance to the water is rocky, despite the presence of sand on the beach area. 18 – 24 year olds seem to be wiling to travel to get to the sand beaches as this age group was more likely to have gone to a sand beach than the older age groups ($\chi^2 = 10.55$, $p = 0.032$). Overall, 72% of respondents went swimming. Barbequing, fishing, and sailing were the activities participated in the least. Only four people who responded to the survey did not participate in any of the activities given. This suggests that tourism in Malta is heavily dependant on the presence of the sea.

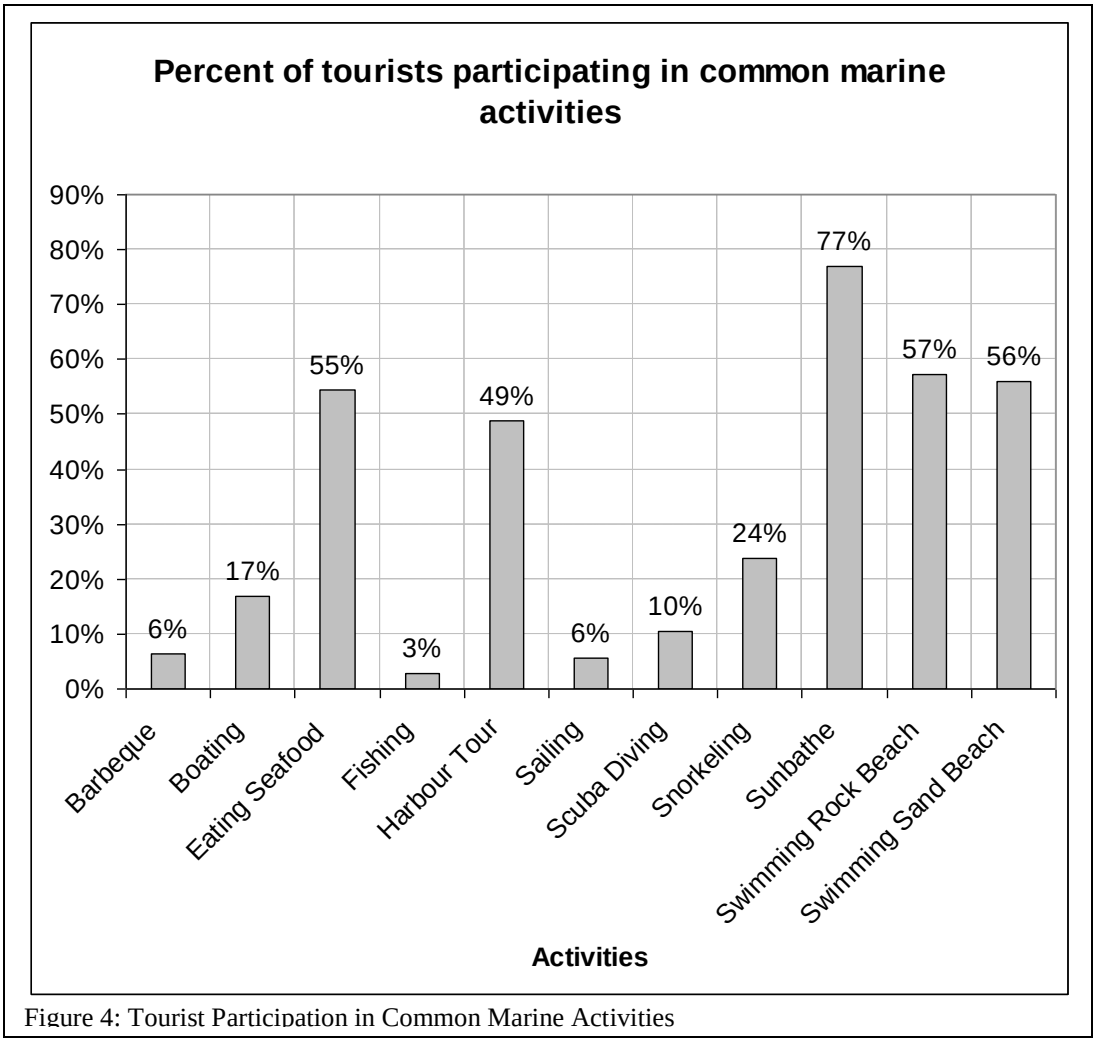


Figure 4: Tourist Participation in Common Marine Activities

Demographic analysis showed that females are more likely to participate in sunbathing than males ($\chi^2 = 5.41$, $p = 0.02$) just as in the resident survey. The younger age groups, $18-25$ and $25-35$ are more likely to snorkel when compared to the older age groups ($\chi^2 = 14.36$, $p = 0.006$). Students were more likely to have gone on a boat during their time in Malta ($\chi^2 = 19.58$, $p = 0.003$). This may be related to the proliferation of 'party boats' that cruise around the island providing alcohol, music, dancing, and panoramic views to its patrons.

4.1.3.d Willingness to pay

Tourists were given the statement "If you were informed that tourism was causing significant harm to the marine environments around Malta would you be willing to:" followed

by five options. These options were: pay a tourism fee upon entering the country, pay a small additional fee for any water related activities, stay at an ecofriendly hotel that might restrict some services, stay at a hotel certified as a "green" hotel, and have to book water related activities in advance due to restrictions of visitor numbers. Of these options, the first two were additional fees, the second two were alternative accommodation, and the last option was simply a book in advance requirement. The tourists' willingness to say they will accept these restrictions and fees is likely to be stronger than their actual willingness to do so. The question is then used as a guideline for possibly policies in the future.

Tourists did not seem to be very amenable to any of the suggestions as only one suggestion, staying at a green hotel, got more than 50% of the respondents support (it had 51%). The difference between those willing to stay in a green hotel versus those who would stay in an 'ecofriendly hotel that might restrict some services' (31%) was surprising. It may just be marketing, as a truly green hotel would restrict some services, such as changing sheets everyday to reduce water use. The one option that would not cost the tourists anything extra, but would require advanced planning, the advanced booking for water activities option was the least favorable with only 21% willing to book activities in advance. It appears that people are less concerned about the money spent and more concerned with the convenience of being able to do what they want when they want.

Only 4% of those surveyed said they would not be willing to accept any of the proposed restrictions. 27% said they would accept a general tourist fee and 35% said they would accept a fee for water specific activities. That 35% was made up of a larger proportion of 51 – 65 year olds ($\chi^2 = 11.56$, $p = 0.021$). This may be because they are less likely to participate in water activities than other groups

4.1.3.e Perception of their own impacts

Another set of questions in the survey used a Likert scale to gauge how tourists perceive their environmental impacts in relation to those of a resident. Respondents were asked how they thought their activities compared to those of a resident. The values on the scale were: much less than residents, somewhat less than residents, the same as residents, somewhat more than residents and much more than residents, with corresponding values from 1 to 5. Figure 5 shows the mean score of each of the impacts assuming three (the same as residents) is equal to zero. From Figure 5 it is easy to see that tourists did not perceive their impacts to be very different from those of a resident. None of the scores was a whole point away from the zero point, and only one, transport emissions was more than half a point away with a mean of 2.41 (std dev = 1.13). Two of the impacts, ocean use and water use were perceived to be slightly more than the residents, with means of 3.11 (std dev = 1.14) and 3.17 (std dev = 1.13), respectively. The rest of the impacts were perceived to be less than those of a resident. Seafood consumption had a mean of 2.50 (std dev = 1.07). Waste production had a mean of 2.69 and electricity consumption had a mean of 2.76 (std dev = 1.15).

The carrying capacity study found that tourists use 1.5 times the electricity and water

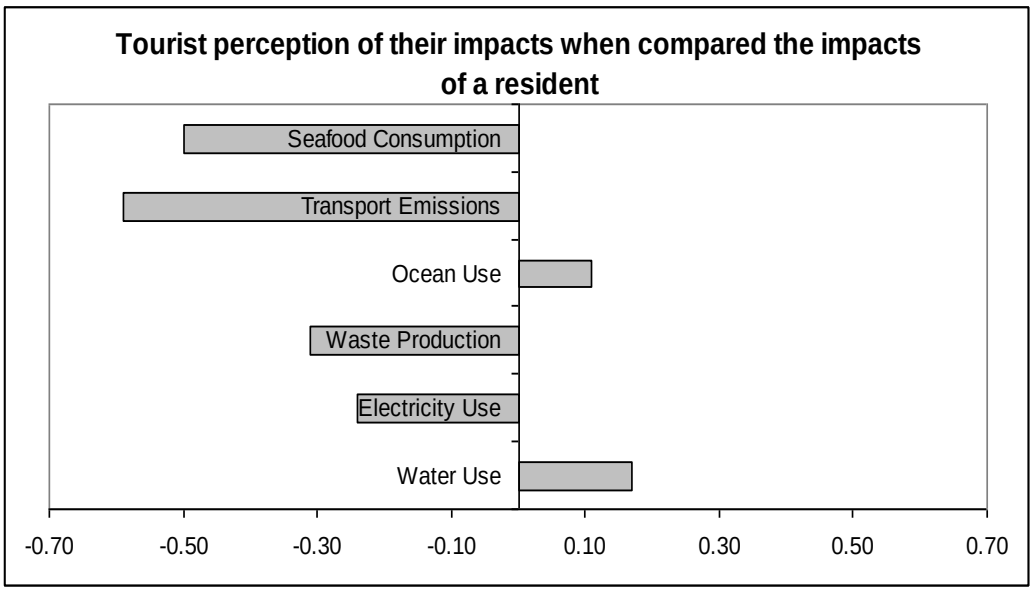


Figure 5: Tourist Perceptions of impacts. *Zero is assumed to be the same as residents

of residents (Mangion, 2001). There is therefore a discrepancy between the impacts that tourists believe that they have and their actual impacts. No data currently exist that compare tourist waste production, ocean use, transportation emissions, or consumption of seafood, with that of residents on Malta. Tourist transport emissions are likely to be higher than residents are since arriving in Malta means flying or taking a boat, though once on the island, tourists are more likely to take public transportation. The carrying capacity study noted that 80% of tourists use public transportation (Mangion, 2001).

4.1.3.f Return Scenarios

The survey next asked "given the following scenarios, would you be much less likely to return, somewhat less likely to return, just as likely to return, somewhat more likely to return, much more likely to return." The seven scenarios were: there was less seafood available; there was increased waste on beaches and in the water; the beauty of marine landscapes declined; water clarity decreased; there were fewer species of fish near the coast; the weather was warmer; and there were more marine protected areas. Figure 6 shows the mean scores assuming that the answer just as likely to return is equal to zero.

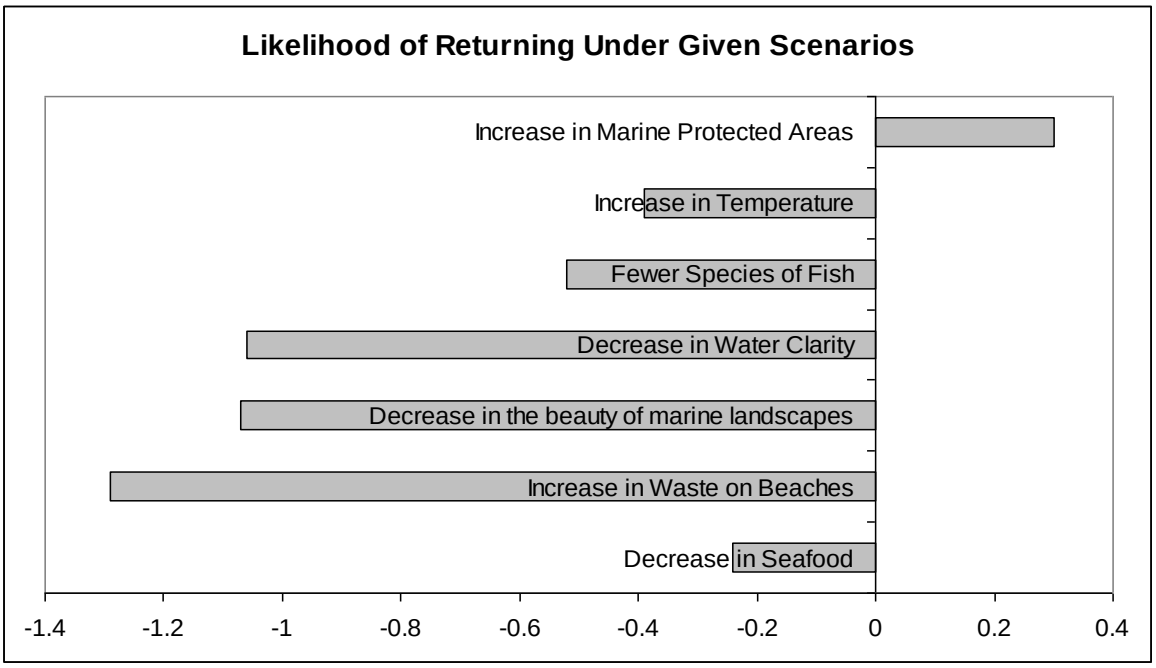


Figure 6: Likelihood that tourists will return given a scenario

Three of the scenarios elicited strong enough responses that the mean was a full point below the neutral answer. These were an increase in waste on beaches (mean = 1.71, std dev = 0.973), a decrease in the beauty of marine landscapes (mean = 1.93, std dev = 0.911) and decrease in water clarity (mean = 1.94, std dev = 0.960). An increase in MPAs (mean = 3.30, std dev = 0.766) was the only scenario to make the respondents more likely to return, though it was not a strong opinion given the mean was only 0.3 above neutral. Increase in temperatures (mean = 2.61, std dev = 0.936), decrease in seafood (mean = 2.76, std dev = 0.669), and a decrease in coastal fish (mean = 2.48, std dev = 0.769) all showed only weakly negative opinions.

It is likely that trash is seen as one of the biggest problems by tourists visiting Malta. In addition to the strong response to the scenario about increasing trash, many of the respondents made comments to the survey takers about the level of trash they noticed. It also appears that preventing the deterioration of water quality should be another priority for tourism management. Ceasing the dumping of raw sewage in the ocean is a step in the right direction. It may be prudent for aquaculture sites to be located away from major dive sites and beaches to maintain clear water for tourist activities.

4.1.3.g Observed Changes

The last question asked respondents if they had been to Malta before, and if so, if they had noticed changes to the marine environments. Only 16 people answered this question. Out of the 16 responses, four mentioned an increase in trash, three mentioned fewer jellyfish, and two mentioned more crowding. Other changes mentioned were both more and less marine life, decreases in water quality, and increased pollution. From the answers, it was difficult to obtain a temporal scale for these changes. These assessments parallel several of the assessments made by residents about changes that they had observed.

4.1.4 Comparing Tourists and Residents

The tourist and resident surveys were designed to have one question similar enough to be able to compare the answers the two populations gave. This was the question about the activities in which the respondent had participated. There were two small differences between the questions. Tourists were given one category for barbeques and recreational fishing, instead of splitting it into sand and rock beaches for the barbeque and boat and shore for fishing as it was for the residents. When compiling the data for this step, if residents had participated in either of the two barbeque options or either of the two fishing options, they were considered as having participated in barbequing or recreational fishing. Once completed, the two populations could be compared.

Of all of the activities in which the two groups participated unequally, the residents were always the group that was more likely to participate. This may be related to the fact that residents have more of an opportunity to participate in these activities, as they are present year round instead of for just a short time. Another possible explanation is that the need for additional equipment for many of these activities may have been prohibitive, whether by cost or by opportunity. For example, Malta has very few public barbeques, so for a tourist to have barbequed, they either must know someone who has a grill, or purchase one themselves. Similarly, if a tourist did not arrive by sailboat, it is less likely that they would have access to one, or if they did have access, it is likely to be prohibitively expensive.

In nine of the eleven activities that were given, respondents that indicated that those participating were more likely to have been residents. The strongest pattern of these differences was for barbequing ($\chi^2 = 255.24$, $p = 0.000$) where 94% of residents had participated, but only 6% of tourists did. This activity as well as the next two activities with the strongest differences, fishing ($\chi^2 = 149.93$, $p = 0.000$), and sailing ($\chi^2 = 84.46$, $p = 0.000$), require some sort of equipment that is expensive or difficult to rent. Boating ($\chi^2 = 48.99$, $p = 0.000$) and

snorkeling ($\chi^2 = 45.35$, p = 0.000) have similar patterns of participation. Their high chi squared values are most likely due to equipment requirements as well; however it is much easier to rent snorkel gear or motor boat time than to acquire the equipment needed for the three previous activities. Swimming from rocky beaches ($\chi^2 = 59.06$, p = 0.000), swimming from sandy beaches ($\chi^2 = 58.48$, p = 0.000) and eating seafood ($\chi^2 = 34.45$, p = 0.000) also show a high chi squared value. This is probably due to the popularity of these activities among the Maltese. Each of these activities had more than 80% of residents participating in them. Scuba Diving participation was also different between the tourists and residents ($\chi^2 = 15.75$, p = 0.000). This shows that it may not be possible to assume that residents and tourists are participating in the same activities and thus combining recreational and tourism activities and impacts together during further analyses is inadvisable.

4.1.5 Diver Survey

4.1.5.a Demographic Profile

54 diver surveys were completed representing people from 13 countries. The largest portion of those who responded was British (19) or Maltese (15). All other countries were represented in small numbers. 5 of the respondents were from Finland, as there was a Finnish dive club present during one of the survey times. Other countries represented were Germany, Turkey, Ireland, Austria, France, New Zealand, Spain, Switzerland, Sweden, and the United States. Of the 54 respondents, 14 were female, and 40 were male, a proportion that is not significantly different from the proportion of residents reporting that they had been scuba diving ($\chi^2 = 2.48$, p = 0.11). Respondents represented a wide range of professions. However, the small sample size made it pointless to use profession as a category for analysis. However, as 14 of the respondents listed their profession as dive master or dive instructor, the samples were divided between those in a diving profession and those in another profession for further investigation. Respondents were further categorized by age, of which the largest portion (43%) was between the ages of 36 and 50. 26% of respondents were between the ages of 25 and 35, 19% were between 51 and 65 and 13% were between the ages of 18 and 24. Additionally, 15

responses from the tourist survey were included when asked, "Why did you decide to dive in Malta?"

4.1.5.b Reasons for Diving in Malta

Respondents were asked why they choose to dive in Malta. The most common reason given for diving in Malta was that respondents lived in Malta (15). Other reasons were provided that included a reputation as one of the best places to dive in the Mediterranean (9), recommendations (5), easy access to all dive sites (9), good visibility (8), and the large number of wrecks available to dive (6). Those responding to the tourist survey were more likely to respond with answers like "chance," "adventure," or "because I was here."

4.1.5.c Habitat Preferences

Divers were asked to rank their preferences of habitat to dive on from 1 to 5, when given the choice between wrecks, seagrass meadows, interesting rock formations, rocky algal reefs, sandy bottoms, caverns or caves, and drop-offs. Only 48 responses were used for this question as several people had misunderstood and gave multiple habitats the same rating. The most favored habitat was clearly wrecks, with an average score of 1.83 (std dev = 1.098). The habitat with the second highest ranking was interesting rock formations with a mean of 2.65 (std dev = 1.229). Caverns and drop-offs were closely ranked for third with mean scores of 3.31 (std dev = 1.824) and 3.81 (std dev = 1.539) respectively. Rocky algal reefs received the next highest score with a mean of 4.44 (std dev = 1.335) followed by seagrass beds with a mean of 5.71 (std dev = 1.443). The least favored habitat was sandy bottoms, with a score of 6.25 (std dev = 0.887). Based on these results and the answers from the previous question, it is clear that Malta's wrecks are a big draw for divers.

4.1.5.d Important Dive Characteristics

Divers were next asked to rank the factors contributing to their choice of dive site from 1 to 10. The factors to be ranked were water clarity (also known as visibility to the diving

community), a large number of different species, interesting underwater landscapes, intentionally placed statues, chains, plaques or other human elements, water temperature, the dive company's choice, the presence or absence of strong currents, the depth of the dive, the quantity of fish, and the diversity of fish. The rankings for this question were not as clearly delineated and the differences in the means were much smaller and frequently within one standard deviation of each other. The large number of species category was the most favorably ranked, with a mean of 3.25 (std dev = 2.383). This was followed closely by an interesting landscape (mean = 3.75 std dev = 1.941), clarity of the water (mean = 4.08, std dev = 2.491), fish diversity (mean = 4.48, std dev = 2.560) and fish abundance (mean = 4.52, std dev = 2.634). The less popular factors selected were human elements (mean 6.94, std dev = 2.365), currents (mean = 7.10, std dev = 1.992), temperature (mean = 7.21, std dev = 2.405) and lastly the dive company's choice (mean 7.44, std dev = 3.010). This shows that increasing or maintaining current levels of biodiversity, preservation of the landscape and preserving the high level of water clarity Malta currently has, are key elements in maintaining a strong dive tourism population on Malta. These factors are areas where policies and human actions can drive changes or prevent them.

4.1.5.e Marine Protected Areas and Diver Harm

The survey asked respondents to indicate if they were aware of Malta's Marine Protected Areas. 60% of respondents were aware of the presence of Malta's MPAs. Older divers were more likely to be aware of the MPAs than younger divers were ($\chi^2 = 8.54$, $p = 0.036$). This is interesting as the designation of the first marine protected area in Malta only occurred in 2008, and the later four were established in 2010 (Cousin). These recent dates are from periods that all of the age groups would be able to remember. This suggests that perhaps older, more experienced divers may be more inclined to research the locations where they choose to dive. Since there are no restrictions on activities taking place within the MPAs, it is

likely that the knowledge of the existence of the MPAs is dependant upon some sort of research, whether from MEPA, the newspaper, book about diving, or from a dive center.

Respondents were then asked how often they had noticed other divers causing harm to the marine ecosystem. 61% of the sample had noticed divers doing damage at least once. The frequency that they noticed these changes varied from rarely to every dive. A few people mentioned specifics such as anchoring, littering, spear-fishing (which is illegal on scuba), harassing octopuses, and picking up shells. No one mentioned stirring up sediment, air bubbles trapped in caves, removal of algae, or trampling – the common diver impacts mentioned by researchers (Bellan & Bellan-Santini, 2001; Davis & Tisdell, 1995; Dearden et al., 2007; 2007; Di Franco et al., 2009; Luna et al., 2009). Respondents also mentioned that fishermen and beachgoers also had an impact on the marine environment, citing poor practices and litter as the main causes. 100% of those working for a dive company said that they had observed divers doing harm to the environment ($\chi^2 = 12.03$, $p = 0.000$). This is probably related to both the frequency of their diving, as well as their tendency to take out new or inexperienced divers. More experienced divers tend to go diving without a dive master or instructor.

4.1.5.f Observed Changes to Dive Sites

Only 38 respondents answered the questions about observing changes to dive sites. Divers were asked if they had noticed changes to the range of extent of ecosystems, the type, number or size of species, the amount or extent of trash, and the amount or extent of other pollution. The largest percentage of people (61%) said that they had noticed changes to the type number or size of species. 58% of the sample said that they had noticed changes to the amount or extent of trash. 55% said they had noticed changes to the range and extent of ecosystems. 51% noticed changes to the amount or extent of other pollution. The smallest proportion of people, 39% said that they had noticed changes to water clarity. Changes to ecosystems and pollution were both more likely to be observed by divers over the age of 55 ($\chi^2 = 8.90$, $p =$

0.031) (χ^2 = 9.81, p = 0.020). This may be an indicator of the length of time needed for these changes to occur. This is an important factor to consider when examining ecosystem changes. Without extensive records, it is possible for the baseline to shift as generations age without succeeding generations noticing a difference.

It was not specified in the survey if changes should be of a positive or negative nature. This was reflected in the descriptions of changes and emphasizes the anecdotal nature of these observations as often when some responses indicated one type of change, other responses indicated an opposite change. The most common change discussed was levels of trash. Seven people said that trash levels increased, three people said that the level of trash has not changed but has always been high, and three people said that trash levels have decreased. The number of fish was also talked about in contradictory terms, with six people noticing a decrease in fish, and four noticing an increase in fish. Other comments included: five people noticed deterioration in water quality, while 4 people noticed an improvement. Five mentioned noticing new species, while three said they no longer see certain species. Four people observed the sizes of fish becoming smaller.

4.1.5.g. Cessation of Diving

Respondents were asked if there was anything that would make them decide to stop diving. The intent was to see if any of the above changes would cause people to leave and do their diving elsewhere. Answers ranged from silly (*"if there was a Tsunami"* and *"Arriva!"*) to the serious (*"health reasons"*). The most common answer was no, with 45% of the sample saying that nothing would make them stop diving in Malta. The responses with the second highest frequency were: if there was more pollution and if there was less wildlife. Neither of them was very common, only gathering 4 answers each.

4.1.6 Summary of Survey Responses

It seems from the surveys that the sea is an important part of life on Malta for both residents and tourists. Nearly everyone who completed a survey had participated in at least one of the given activities and most had participated in more than one. Residents also associated the sea closely with the identity of Malta, as well as with their sense of self as a citizen of Malta. It is clear that for recreation and leisure activities, the coast has become an important area to facilitate these activities. In identifying pressures, consistently throughout all of the surveys, trash was mentioned as a problem. Residents noted it when discussing human impacts on aesthetics and fishing, tourists selected trash as the strongest reason they would not return and divers noted that trash had increased. This is likely related to the fact that trash is a directly observable pressure. Pollution was another consistent theme throughout the responses though its use here is as a vague term. Pollution can take many forms from noise, to trash, to chemical and its use in these surveys does not give a lot of insight into what the respondents are observing. Residents also consistently mentioned coastal development, aquaculture, and overcrowding as pressures.

It seems that there is not a general understanding by tourists, residents, or divers about their personal impacts upon the environment. When residents were asked about changes to the environment, most respondents blamed tourists, fishermen, developers, or poor management for the negative changes they observed. While they were not specifically asked about their personal impacts or who was responsible for the changes they had observed, these responses blaming somebody else were prominent for aesthetic changes and changes to fishing. Tourists also seemed to be unaware of their impacts, thinking that their impacts were nearly the same as residents in every case that was given, despite evidence that these impacts are in fact much greater. While divers were not specifically asked about their impacts, when asked if they had noticed divers doing harm, a majority had observed it. Despite this, no one mentioned any of the impacts that researchers commonly mention. While most people seem to believe that

human actions can influence the environment, it seems they are unclear about their own personal impacts. If the Maltese government wants to make the preservation of marine and terrestrial ecosystem services a priority, this uncertainty and confusion cannot remain.

When it comes time to discuss the marine environment and the activities that take place there, it will be necessary to couch the discussion in very specific language. The complex ideas of ecosystem services are not well understood by residents as only a third of residents were able to describe this term correctly. Using less scientific terms and explaining processes may be necessary to ensure that the majority of residents can participate in the debate. Of particular note should be the confusion surrounding climate change. More residents said they were unsure if humans could impact climate than said humans could impact climate. However, most of those who were unsure or did not think humans could alter climate, still noticed the climate changing.

4.2 Ecosystem Maps

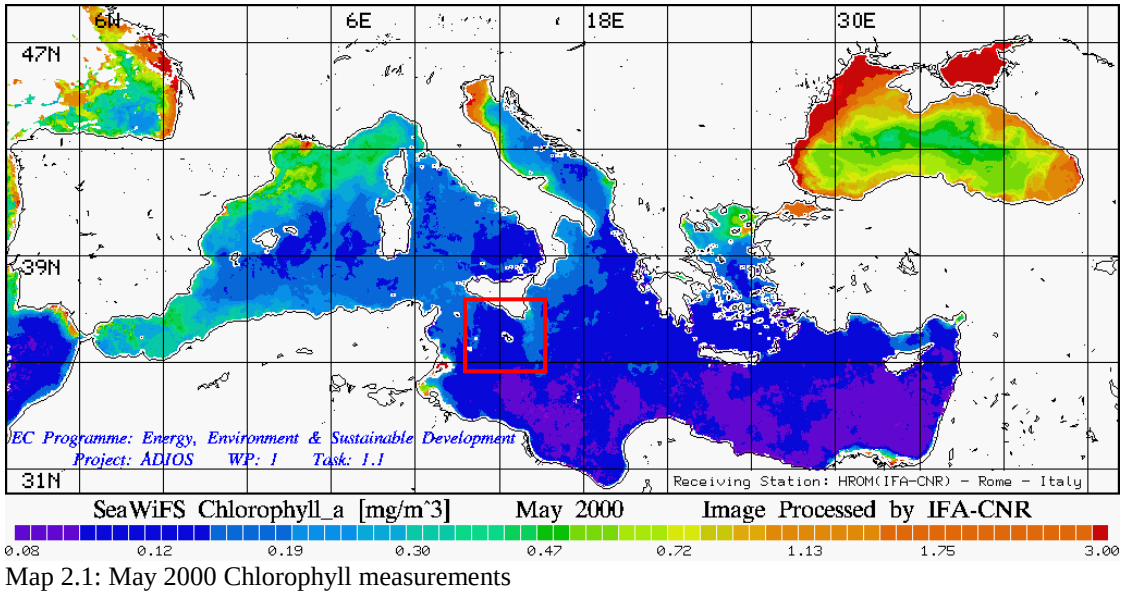
4.2.1 Climate

The ecosystems around Malta that were determined to be important in maintaining climate regulation services included seagrass beds, algal reefs, maerl beds and other areas of high primary productivity as these areas act as a carbon sink, removing CO_2 from the atmosphere (Costanza, 1999; Orth et al., 2006). Areas of phytoplankton concentration were also deemed important as these areas may provide CCN along with decreasing atmospheric CO_2 levels (Andreae & Crutzen, 1997; Andreae & Rosenfeld, 2008; Charlson et al., 1987). Measurements of Chlorophyll α are used as a proxy for phytoplankton measurements as Chlorophyll α can be measured remotely by satellite. The SeaWiFS Chlorophyll data are available from NASA (Feldman, 2011). Several papers discuss an area of upwelling in the Straits of Sicily (Millot & Taupier-Letage, 2005; UN Environment Program, 2004; Wainwright

& Thornes, 2004). It was important to identify if this upwelling area occurred in or around Maltese waters.

For the Atmospheric Deposition and Impact on the Open Mediterranean Sea Project, Santoleri *et al* created composite monthly maps of the Mediterranean data (Santoleri et al., 2001). Data for May 2000 are shown below in Map 2.1. From Map 2.1, it is possible to see that Malta is located in oligotrophic waters, or waters without substantial nutrients to support phytoplankton growth. This suggests that there are no substantial CCN producing patches of phytoplankton around Malta. Because of the small size of the Maltese archipelago, obtaining data on a local scale is difficult. Data on a finer scale could show patches of increased productivity around the islands. However, these patches would likely be too small to cause a noticeable effect in CCN production, especially in comparison to the other aerosols such as dust from the Sahara and air pollution. As a result, this study will not consider plankton rich habitats further.

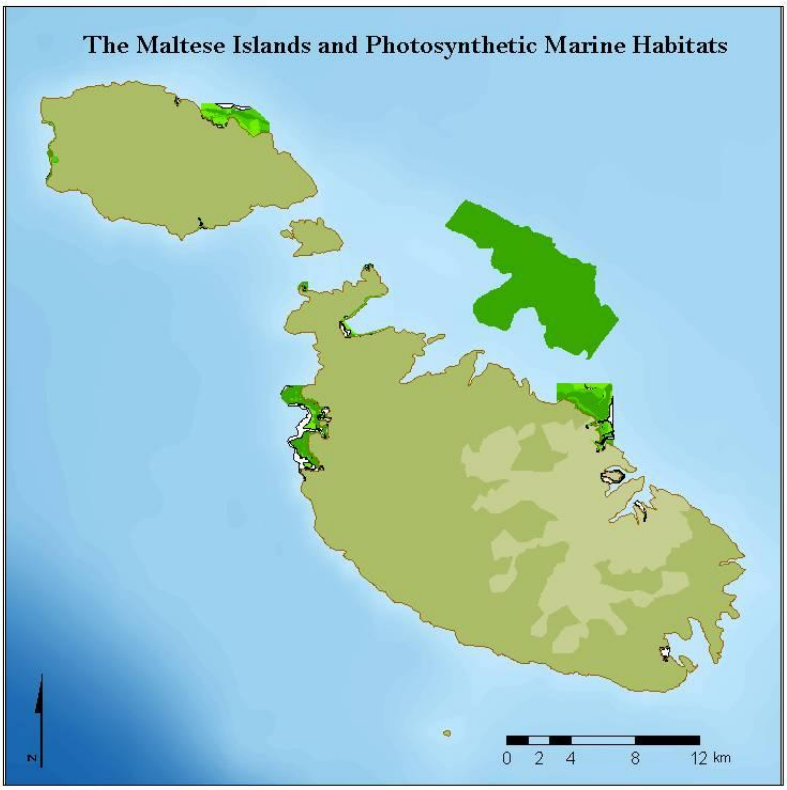
There are several photosynthesis-based marine ecosystems in the waters around Malta. The most important of these are seagrass beds, algal reefs, and maerl beds. Estimated primary



Map 2.1: May 2000 Chlorophyll measurements
Source: {{225 Santoleri, R. 2001}}

production from seagrass beds is higher than that of many cultivated terrestrial lands (Orth et al., 2006). Primary production for *Posidonia oceanica* beds can be as high as 3.4 m^{-2} day^{-1} (Ballesteros, 1989). Dead leaves, rhizomes and roots provide organic carbon to sediments, acting as a carbon sink (Orth et al., 2006). *Cystoseira sp.* dominates the macroalgae communities on Malta (Malta Environment and Planning Authority, 2002; Schembri et al., 2005). These algae have primary production rates between 2 and 9 g C m^{-2} day^{-1} depending on local conditions (Ballesteros, 1989). There are few if any studies that evaluate the carbon sequestration abilities of maerl beds, but laboratory experiments have an estimated annual primary production rate of 10 – 600 g C m^{-2} yr^{-1} for *Lithothamnion coralloides* (S. Martin, Castets, & Clavier, 2006). These three habitats provide carbon sequestration services to Malta.

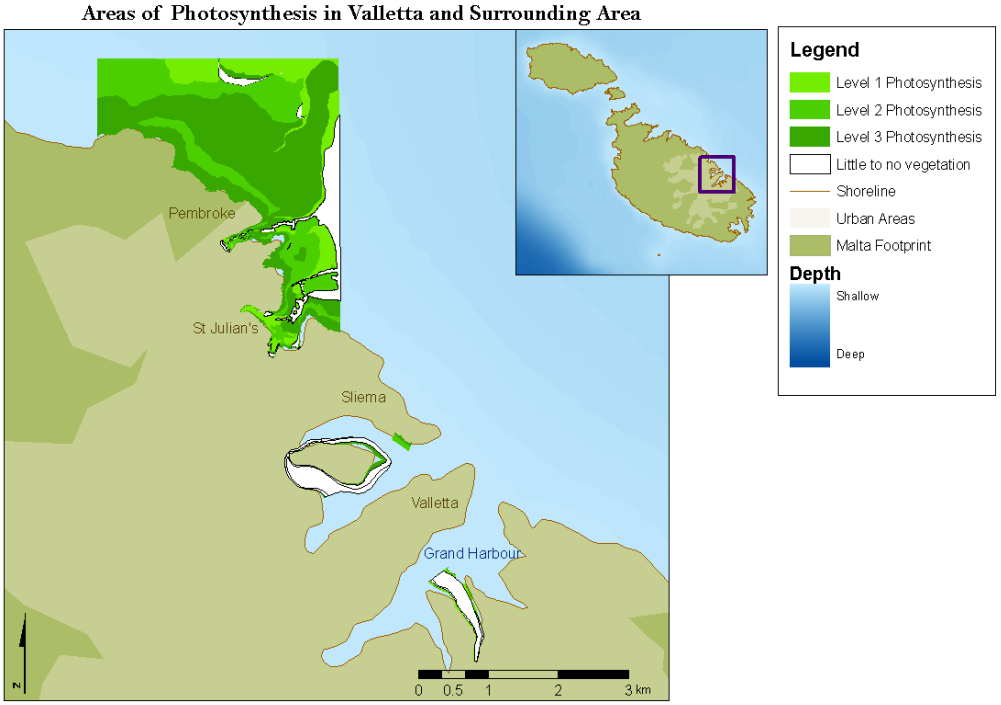
Data were taken from the Marine Habitat Data of the Maltese Islands dataset (J. A. Borg & Schembri P.J., 2002). These data cover 13 areas around the island, identifying polygons using the Regional Activity Center for Specially Protected Areas classification system. These units were too specific for the scope of this project and as such were reclassified into three levels based on the level of coverage of photosynthetic flora in the area. Level one included areas that were primarily non-vegetated, but may contain enclaves of vegetation. Level two zones are areas of patchy coverage, and level three was considered areas of continuous coverage. No distinction was made between seagrass beds, algal reefs and maerl beds as many of the descriptions were of complexes containing multiple habitat types. Separating the habitats by type and attempting to assign rankings based on total primary production is beyond the scope of the current data. The full map of Malta is shown in Map 2.2. It is important to remember that a complete set of habitat data is not available for Malta's coastline. Coastal areas still in blue should be considered data deficient. In addition to the areas shown here from the Habitats Dataset, there are reports of large seagrass beds between Comino and Malta, Comino and Gozo and off the northeast tip of Malta (Malta Environment and Planning Authority, 2002).



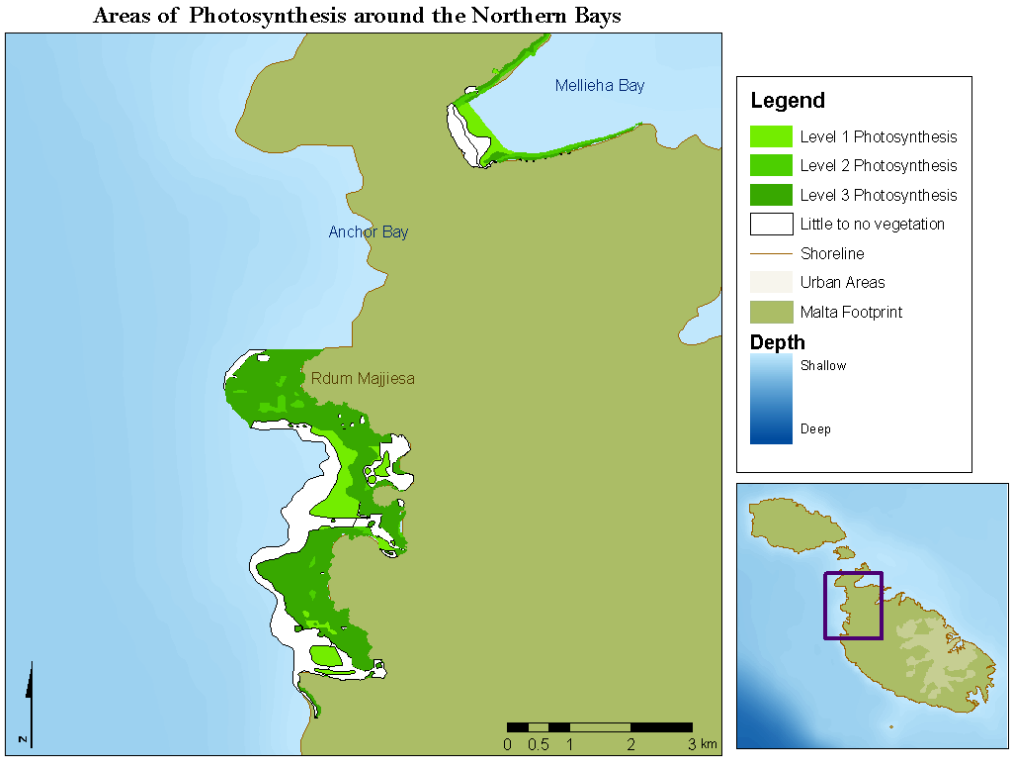
Map 2.2: Photosynthetic Habitats in Malta's Waters

Immediately noticeable from the available data is the large patch of green on the northeast side of Malta. This area represents an extensive maerl bed. To the south, the surveyed area near Birzebbuga, one of the 13 studied areas lacks vegetation (J. A. Borg & Schembri P.J., 2002).

Focusing on Valletta, Sliema, and St Julian's in Map 2.3, it is possible to see that the two harbors surrounding Valletta are mostly unvegetated. Balluta Bay and Spinola Bay show less dense areas of vegetation, but off the coast of Pembroke, there seems to be extensive coverage. This area is a combination of rocky algal reefs and *Posidonia* beds. Further north, in Map 2.4 are the northern bays from Rdum Majjiesa to Ras ir-Raheb and Mellieha Bay. The area from Rdum Majjiesa to Ras ir-Raheb has an area of continuous coverage with some patchy and non-vegetated areas along the beachfront. This area is the only marine Natura 2000 site



Map 2.3: Primary Production in Valletta Sliema, St Julian's and Surrounding Area

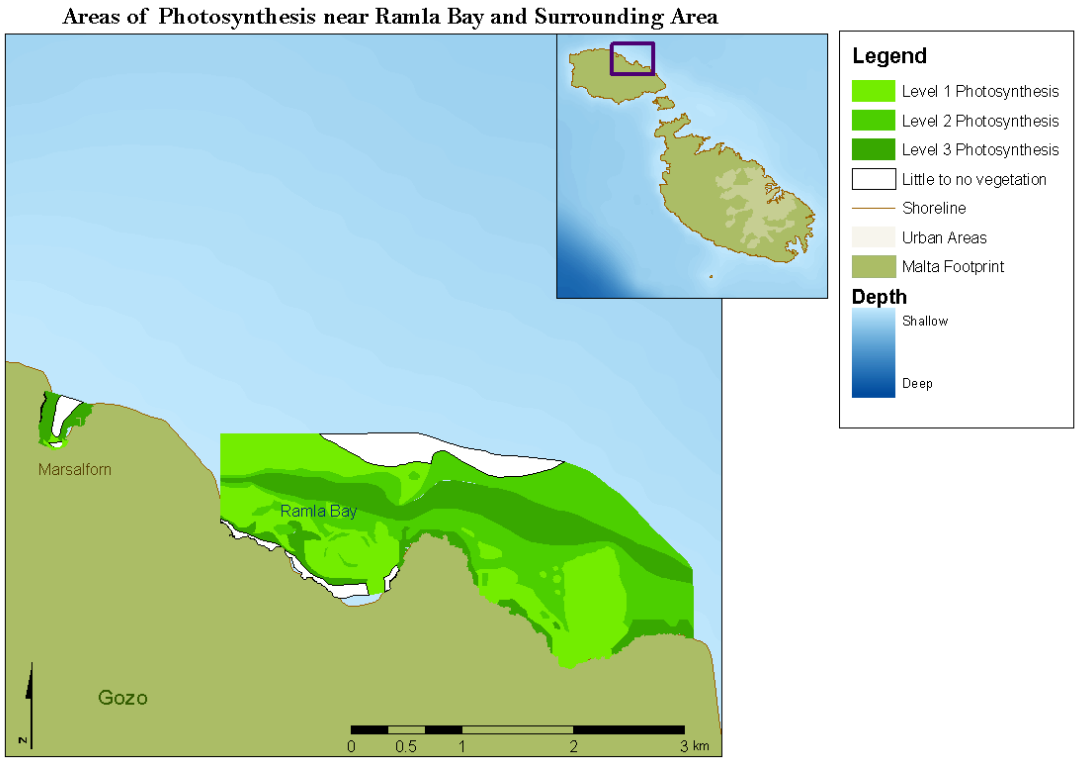


Map 2.4: Photosynthetic habitats around the northern bays

that exists in Malta so far, though there are still no regulations on use (Cousin). The area at Ramla Bay on Gozo shown in Map 2.5 shows a patchy distribution over most of the area.

Since Malta is an island nation, the physical properties of the surrounding Mediterranean Sea play an integral role in determining the climate of the island. Changes to major Mediterranean currents and smaller local currents could potentially alter the climate around the island. Coastal development, thermal pollution from the power plant at Delimara and outflow from the reverse osmosis brine waters have the potential to change local currents (Parnell, Dayton, Lennert-Cody, Rasmussen, & Leichter, 2006). Changes to these local currents and the addition of warm or briny water could alter nearby microclimates (Parnell et al., 2006).

Without a complete habitat map for the coastal region, it is difficult to identify the areas around Malta that need to be protected to ensure climate stability. This is especially true when



Map 2.5: Photosynthetic habitats around Marsalforn, Ramla and San Blas on Gozo

you consider that climate is a worldwide system, and on the global scale, the small amount of primary production occurring in the water off Malta is almost negligible in terms of global carbon sequestration. However, the destruction or degradation of these smaller areas around the globe does add up. These habitats are declining and degrading around the Mediterranean (Terrados & Borum, 2004). Malta should strive to protect them.

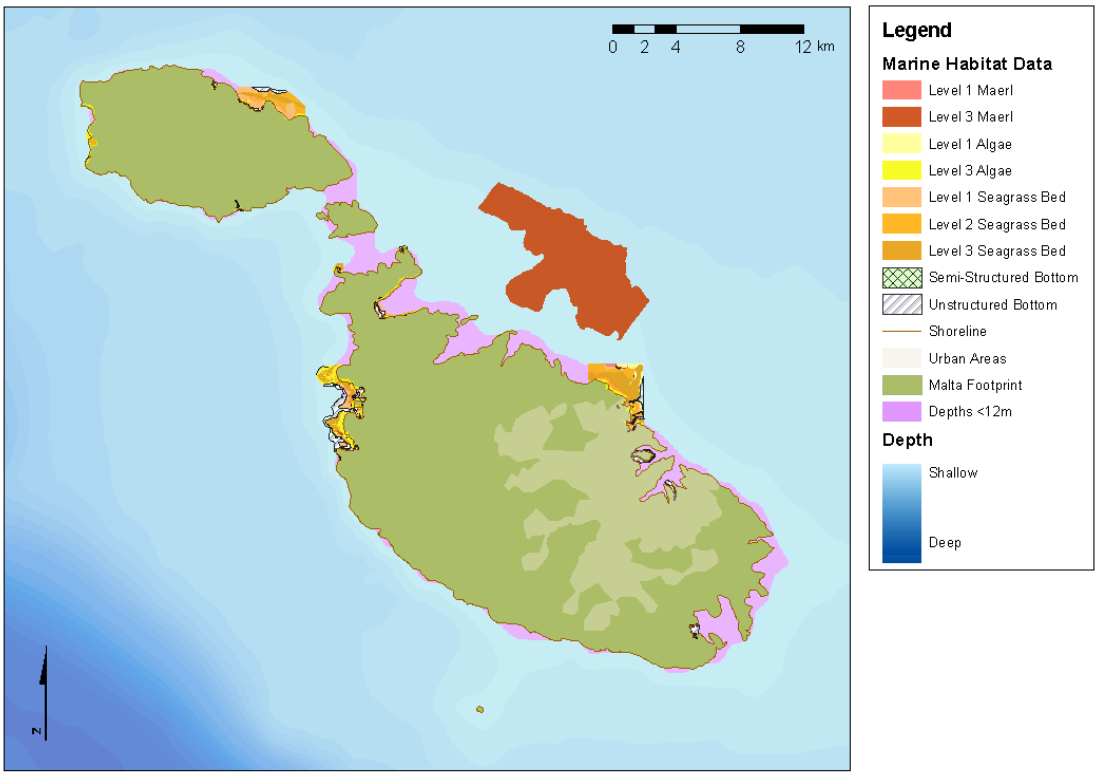
4.2.2 Nursery Habitat

Critical nursery habitat is difficult to determine because the sites where the service occurs are not the same as the sites where people benefit from the service. There are also a number of difficulties in collecting data in marine habitats. This is further complicated by the fact that most fish, even as juveniles, use a mosaic of habitats gaining different benefits from each habitat. Through an extensive literature review and interviews with Maltese biologists, it was determined that the essential nursery habitats around Malta are areas that have increased structural complexity. On Malta, this means seagrass beds, rocky algal reefs and maerl beds. Additionally, a number of fish spend their time as juveniles in shallower water regardless of habitat, and then move to deeper water when they become adults. Several authors mention that Mediterranean fish often live in inshore waters less than 12 meters deep before migrating to the deeper offshore waters as adults (Biagi et al., 1998; Harmelin-Vivien et al., 1995; Millennium Ecosystem Assessment, 2005). The maps for this section will focus on these particular habitats.

Using the bathymetric data compiled by ESRI, coastal areas with depths less than or equal to 12 m have been highlighted in light purple in this set of maps. In addition, the Marine Habitats Data provided by MEPA were used again to identify the other habitats of interest (J. A. Borg & Schembri P.J., 2002). These data were categorized based on the primary assemblage into five habitat groups: maerl beds, rocky algal reefs, seagrass beds, semi-structured bottoms, and unstructured bottoms. Each of the maerl, algae and seagrass habitat groups were further divided into three levels with level 1 being the least continuous habitat and level 3 being the

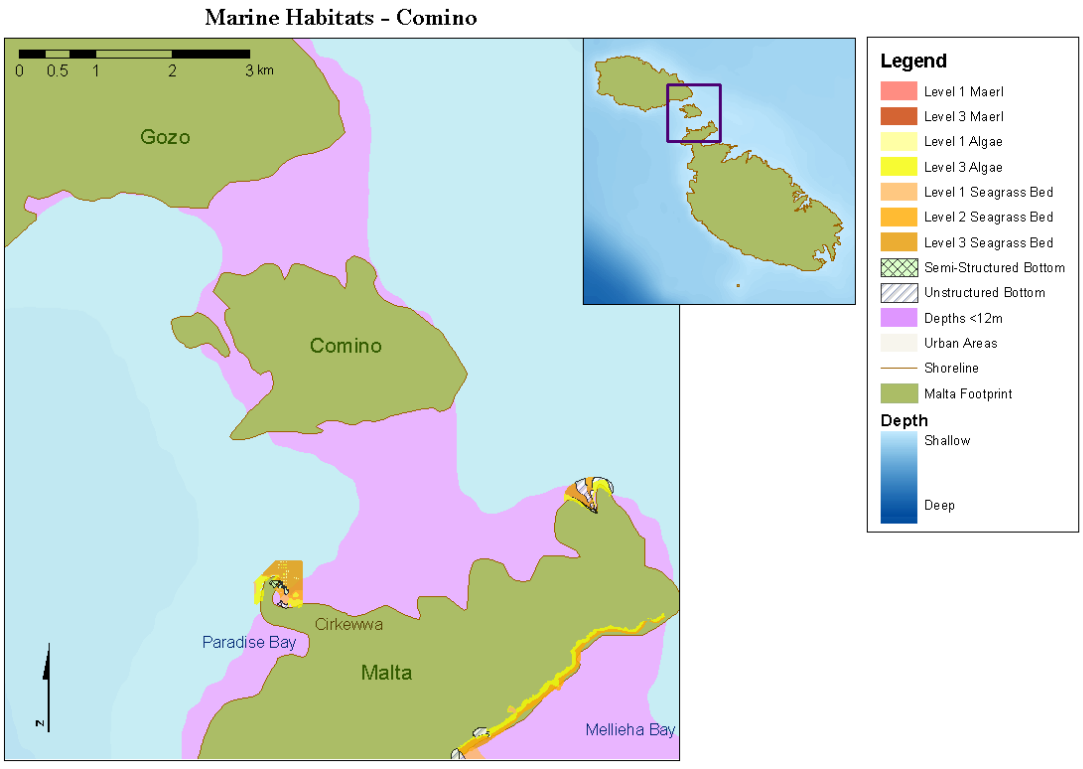
most continuous habitat. Semi-structured bottoms refer to areas of stones, rocks, or pebbles with no associated vegetation. The scope of these data is limited; only 13 areas around the island have been surveyed. Some assumptions can be made for the areas not surveyed. Areas shallower than twelve meters most likely have one of these three structured habitats present, except in areas of heavy boat traffic, sandy beaches, or other source of activity. The resulting map is shown in Map 3.1

Map 3.1 shows that the large majority of the critical habitats are on the eastern side of the island where depth increases gradually offshore. The southwestern part of the island has steep slopes and almost immediate drop-offs, indicating that this is probably not an area of promising nursery habitat. Map 3.2 shows the water between Gozo and Comino and Comino

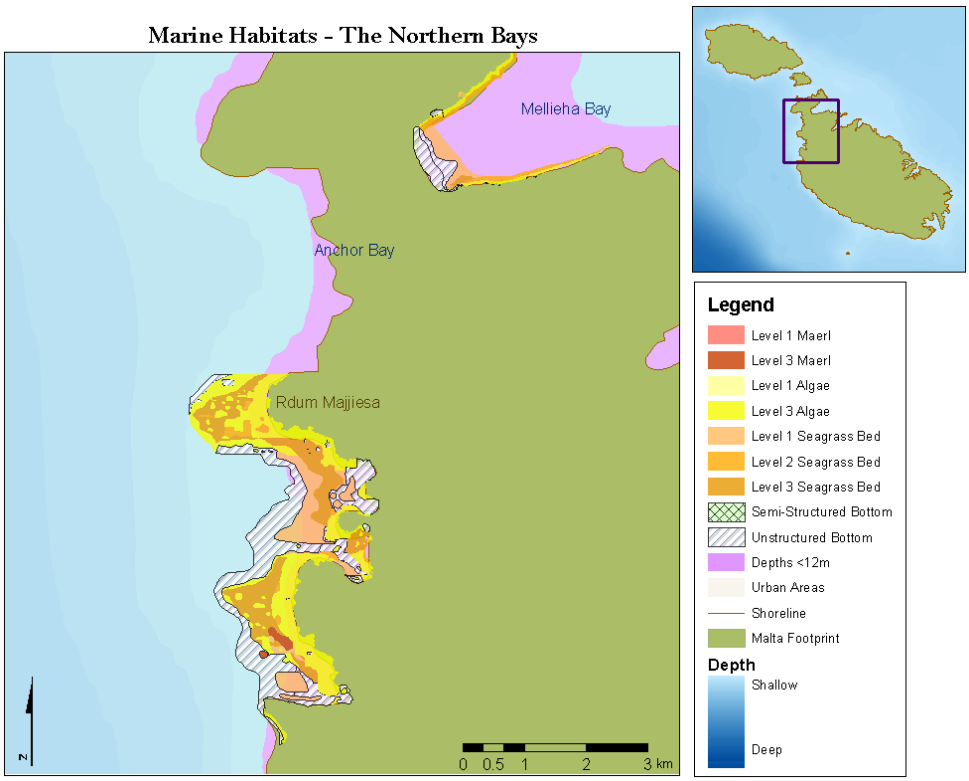


Map 3.1 Critical Nursery Habitats around Malta.

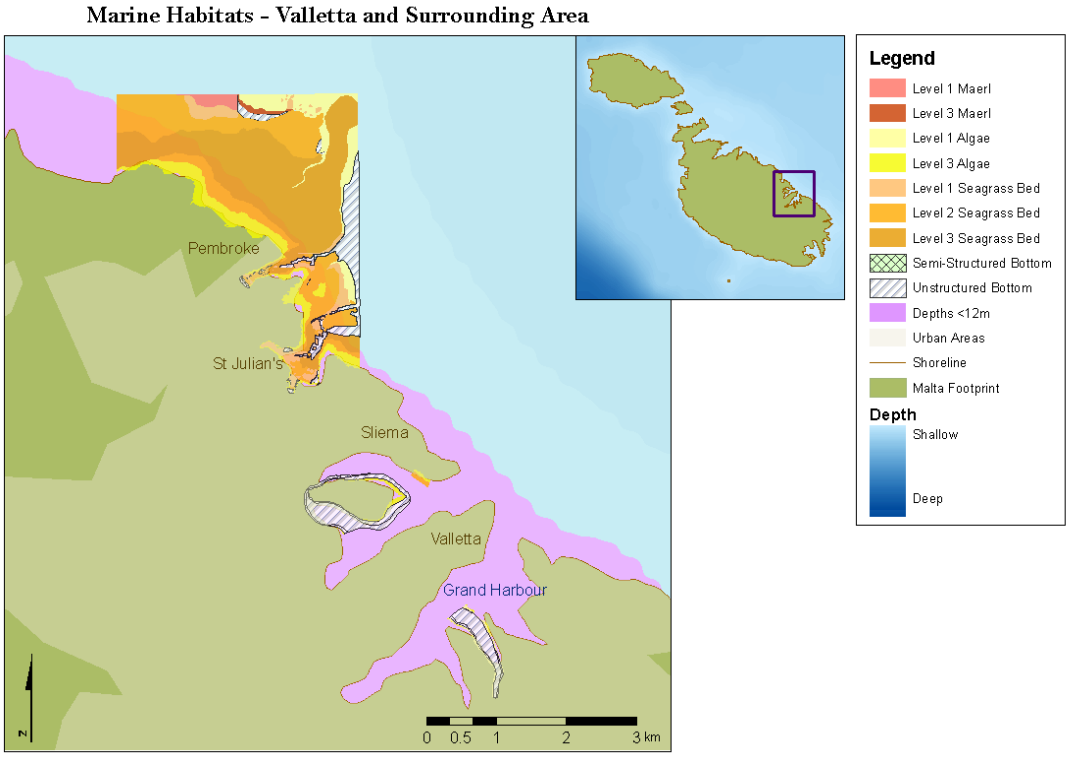
and Malta is shallow enough to be suitable nursery habitat. Map 3.3 shows the Northern Bays. It is possible to see that the areas with unstructured bottoms are the sites of the island's most popular beaches. Map 3.4 shows the area around St Julian's, Sliema, and Valletta. When comparing this map to the other nursery maps, a general pattern can be seen in the location of the different habitats. At the furthest inland areas, where there is a bay, there is usually unstructured bottom. Along the sides of the bay, closest to shore are rocky algal reefs. Further offshore, the seagrass beds start to form. This pattern is also visible in Map 3.5 of the Ramla Bay area in Gozo. There also appears to be an edge effect along the seagrass meadows, where the level 3 continuous meadows are surrounded with level 1 or 2 fragmented meadows. The near-shore areas that appear to be the most important nursery habitats are also the most vulnerable to human impacts.



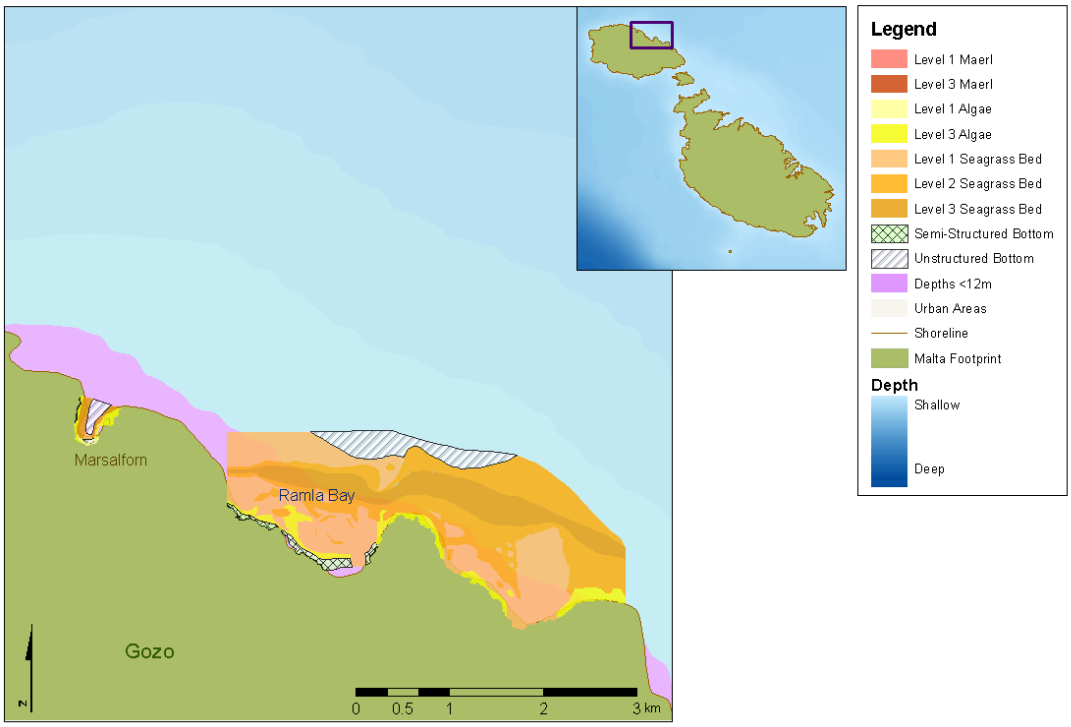
Map 3.2 Nursery Habitats in the Gozo and Comino Channels



Map 3.3 Nursery Habitats in the Northern Bays



Map 3.4 Nursery Habitats in St Julian's, Sliema, Valletta and Surrounding Area



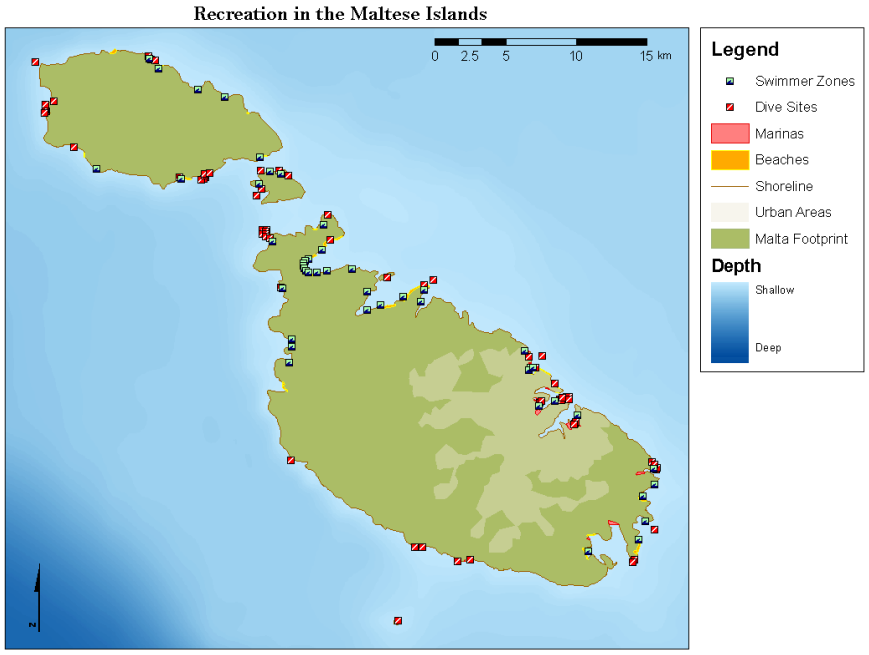
Map 3.5 Nursery Habitats in the Ramla Bay area

4.2.3 Tourism and Recreation

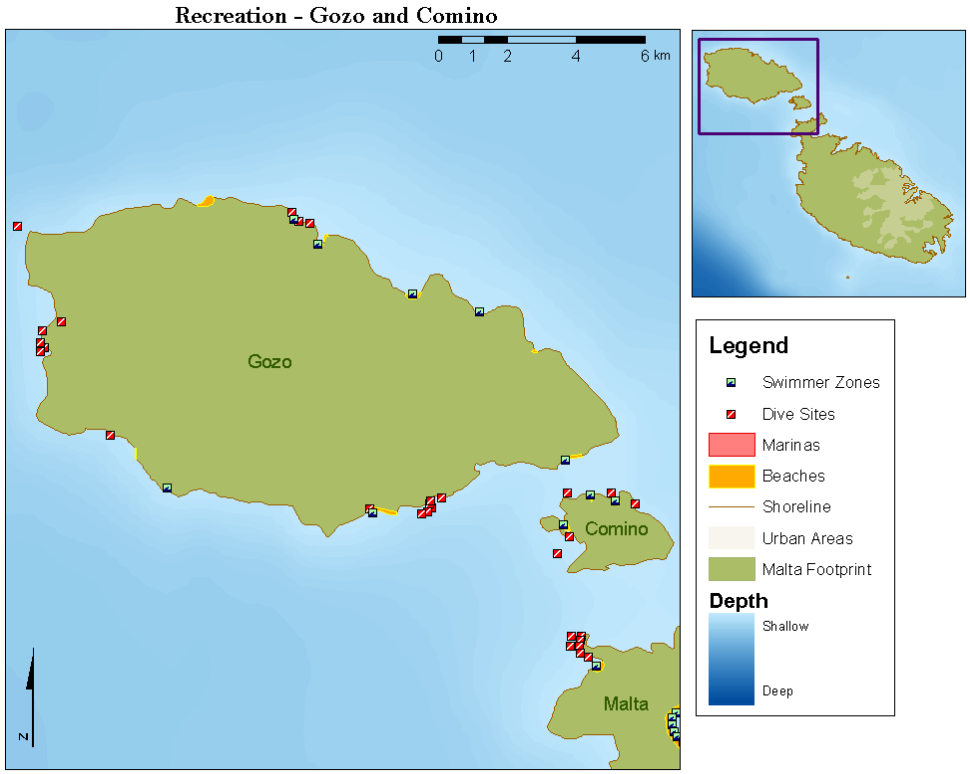
From the Resident and Tourist surveys collected for this study, the top three activities (swimming at a rocky or sandy beach and sunbathing) all take place at a beach emphasizing the importance of beaches and swimmer's zones to recreation and leisure on Malta. While most of the accessible coast can be used as a beach, the beaches identified for these maps are the beaches described on the official tourism site of the Maltese Islands. These are the main beaches used by residents and tourists. The popularity of boating (53%) and sailing (54%) among residents means that marinas are also areas of importance for this ecosystem service. The marinas were identified from the satellite images shown in Google Maps. Commercial wharfs and marinas were not included. The last group of areas identified as important to recreation are dive sites. Identifying dive sites is difficult as around Malta, with a boat, anywhere off the coast can be a wonderful dive site. As a result, most of the dives shown are shore dives. Popular boat dives and wrecks are identified where possible. The dive sites identified on the map have been

compiled from the book Scuba Diving: Malta, Gozo, and Comino by Peter Lemon, the tourism site for the Maltese Islands and the brochure from Dive Systems, one of the larger diving organizations on Malta. The full map of Malta can be seen in Map 4.1. The important areas are spread out around the three islands.

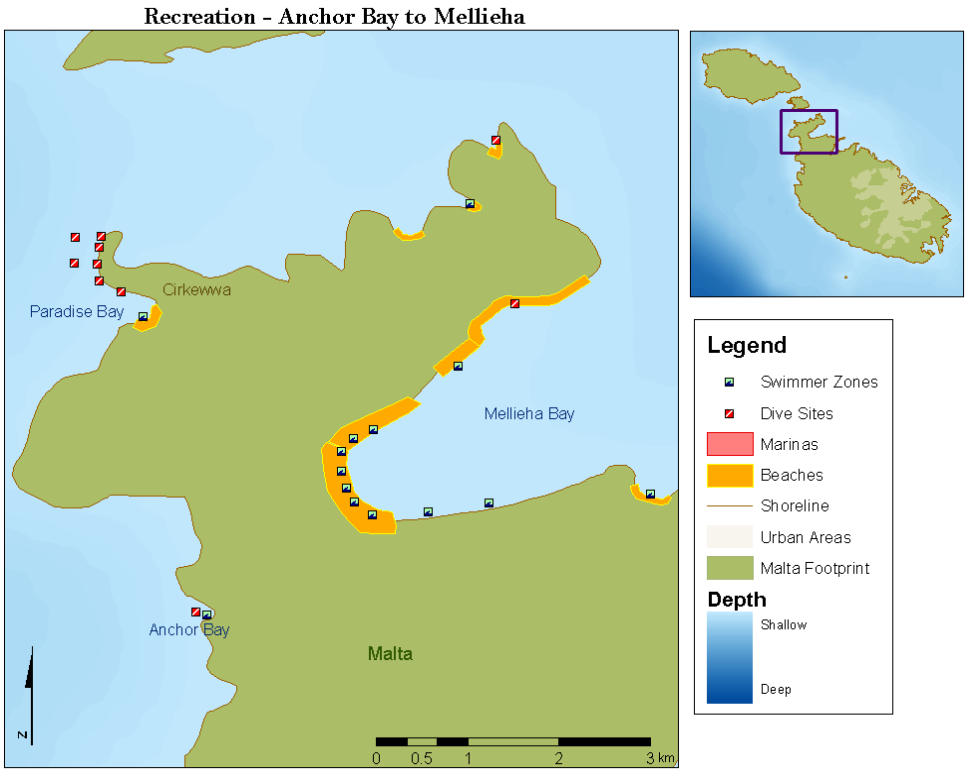
Map 4.2 to Maps 4.5 show a closer view of some of the major leisure and recreation areas around the islands. Map 4.2 shows the important recreation areas around Gozo and Comino. There are thirteen beaches, six areas of diving, and ten swimming zones spread out around the two islands. Map 4.3 shows the area along the northern coast of Malta from Anchor Bay, North and around to Mellieha. Mellieha is a hub of recreation activity with a large beach area, and swimming zones. While there are no marinas in this area, this area is full of boats and jet skis for people to rent and use. Cirkewwa is a hotspot for diving. There is a special parking lot reserved for divers that is filled frequently in the summertime. Map 4.4 shows the area from St Georges Bay to the Grand Harbour. This area has more marinas than most of the other areas as well as several small beaches. The area around Zonqor shown in Map 4.5 is more of a resident locale than a tourist one. It has a number of beaches, swimming zones, dive sites and marinas that are not frequently visited by tourists.



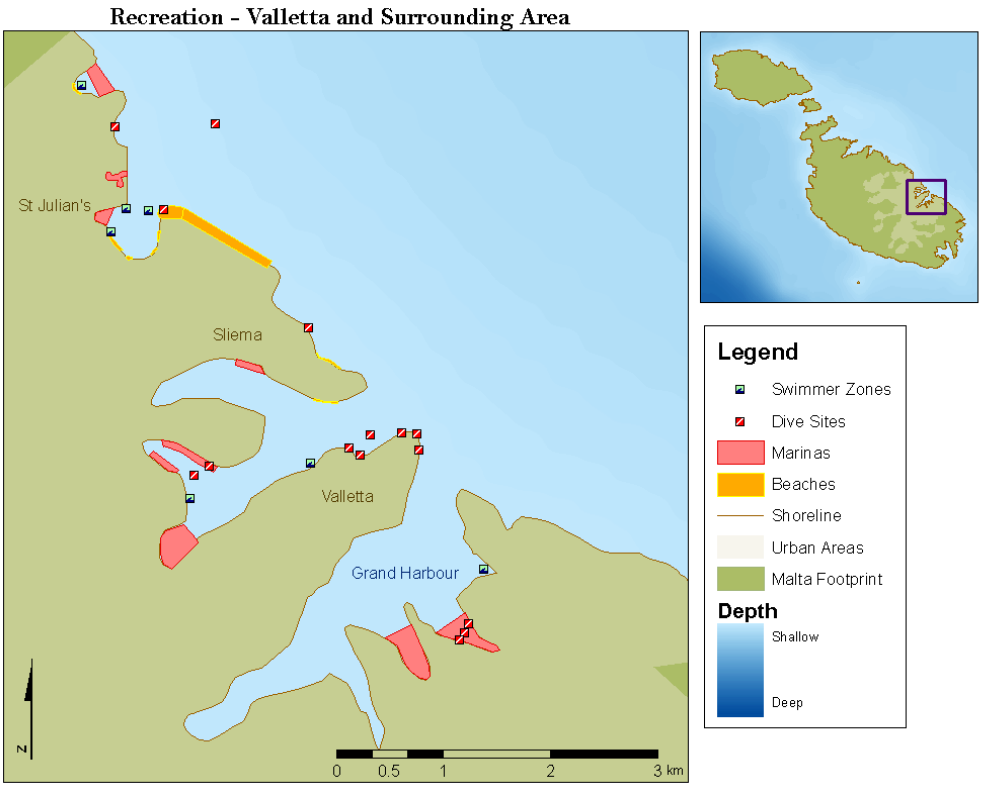
Map 4.1 Areas of Marine Based Recreation on Malta



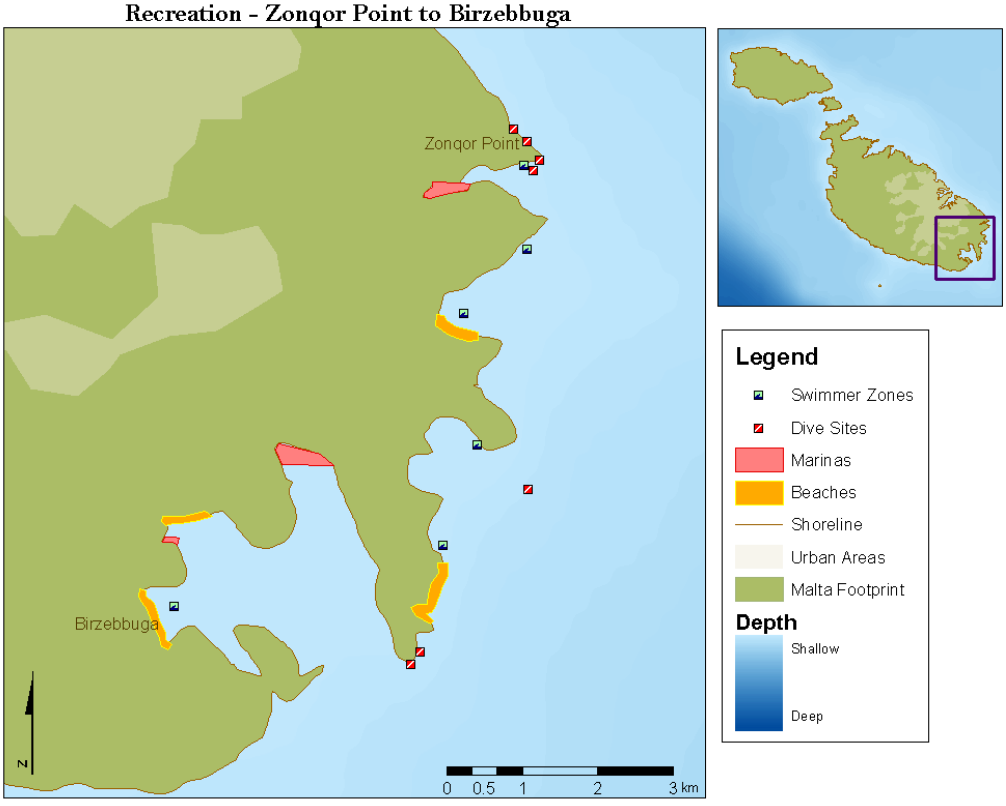
Map 4.2 Recreation Areas in Gozo and Comino



Map 4.3 Recreation Areas in Anchor Bay, Cirkewwa, Mellieha and Surrounding Area



Map 4.4 Recreation Areas in St Julian's, Sliema, Valletta and the Grand Harbour

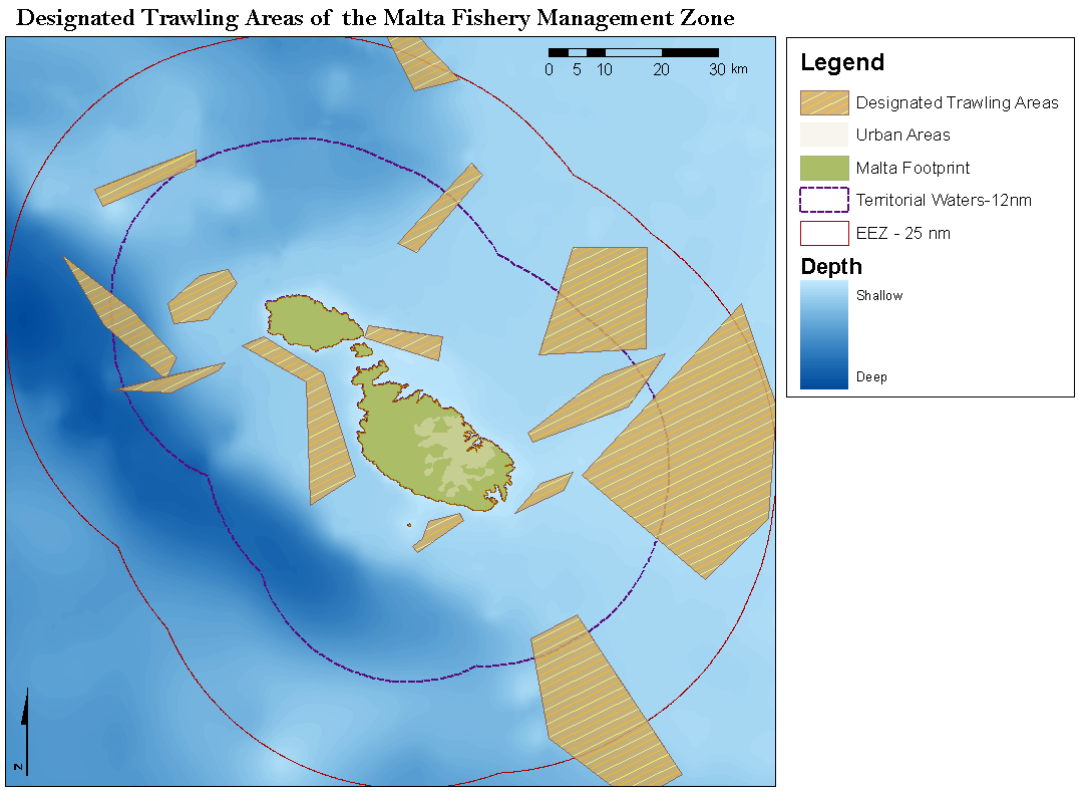


Map 4.5 Recreation Areas from Zonqor Point to Birzebbuga

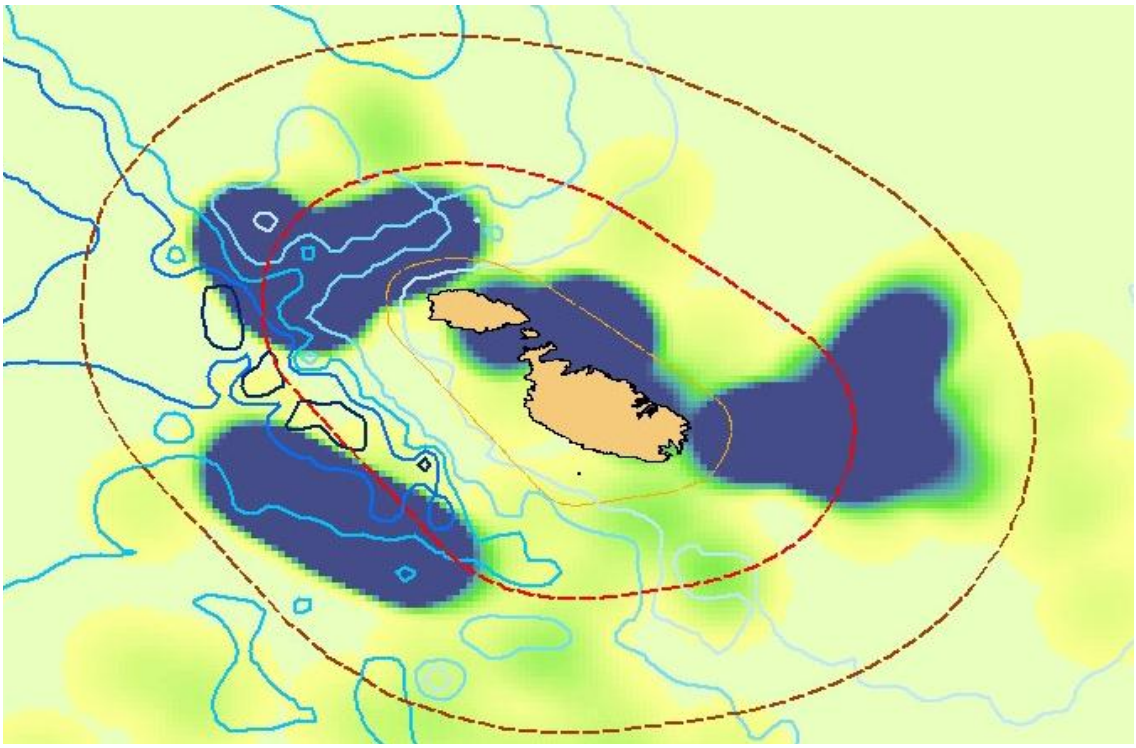
4.2.4 Activities that Impact the Critical Habitats

The three critical habitats for the climate regulation service are the same as the important habitats for the nursery service. These habitats are located close to the shore, which makes them more vulnerable to human impacts. Because they are 'land adjacent,' they are more accessible to people and more likely to be affected by what happens on the land. Coastal development threatens these habitats because it changes sediment patterns and local currents. With Malta being such a small island and increasing its population, it is likely that there will continue to be developments along the coastline. Areas that are adjacent to urbanized areas are most at risk. Of the areas surveyed for the Marine Habitat Dataset (J. A. Borg & Schembri P.J., 2002), the quality habitat adjacent to the Pembroke area shown in Map 5.7 and 5.8 is likely the area that is at the greatest risk of being affected by increased development.

There are a number of other activities that threaten the three critical ecosystems for climate regulation and nursery habitat. One such significant activity is trawling. There are only 15 licensed trawlers in Malta and trawling is closed to outsiders according to the agreement establishing the FMZ. There are 14 designated trawling zones that were created when the FMZ was established (shown in Map 5.1). One of these areas occurs within one of the designated MPAs. Despite these designated areas, data from the 2006 Vessel Monitoring Systems (VMS) installed on every trawler show 4 primary areas that are actually trawled (Darmanin & Dimech, 2007). These data shown in Map 5.2, were presented by Dr. Maria Attard for the Malta Centre of Fisheries Science. These 4 areas of heavy use are not in the same areas as the FMZ designated areas. Trawling occurs at high levels across the northeastern coast including between the three main islands, east of the southern tip of Malta in an area known as Hurd Bank, to the northwest of Gozo and over the deep water trench to the southwest. One of the areas of heavy use occurs over two of Malta's five MPAs (MPAs are shown in Map 5.10), as



Map 5.1: Designated Trawling Areas

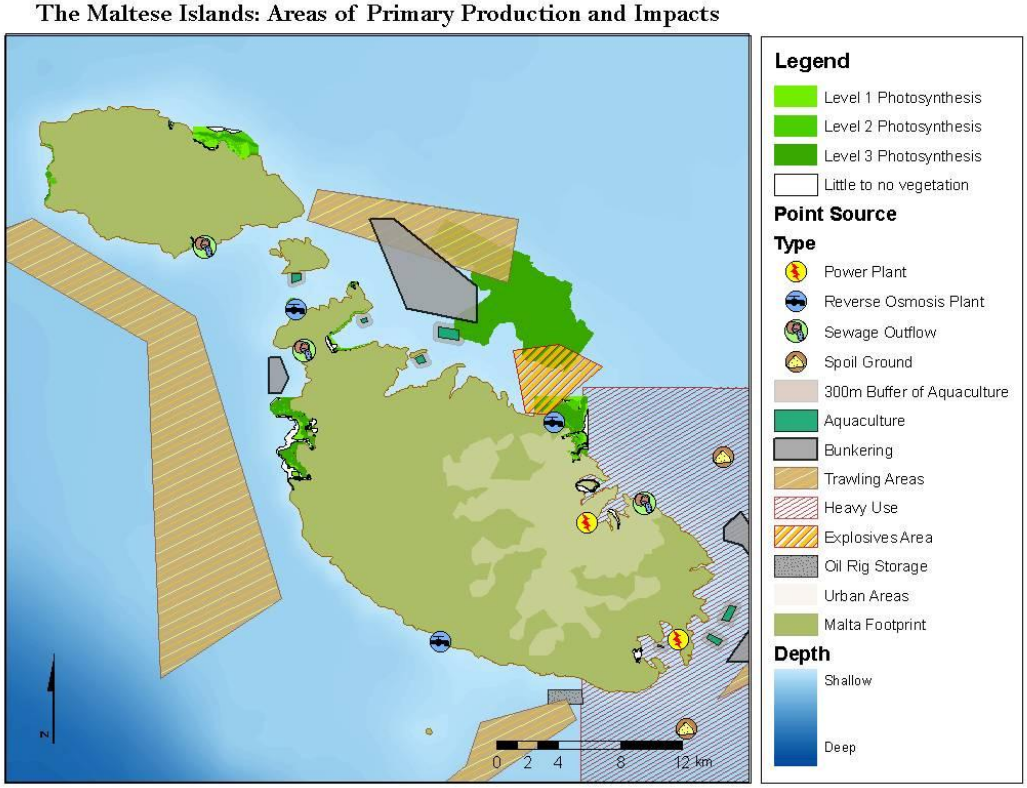


Map 5.2: Trawling Areas from 2006 VMS data
Source: Created by Dr. Maria Attard – University of Malta {{211 Darmanin, M. 2007}}

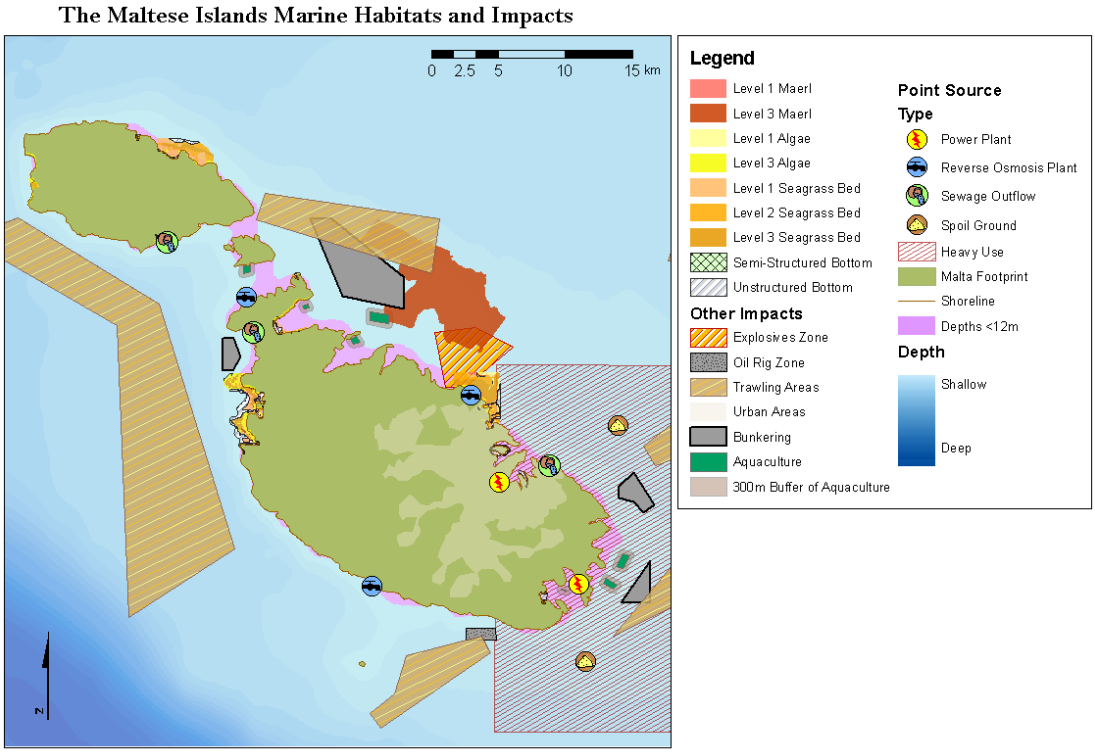
well as over the area thought to have the best and largest area of seagrass beds. The fact that the trawlers show a disregard to the designated trawling areas does not bode well for attempts at protecting the MPAs and the critical seagrass, algae and maerl habitats. Trawling causes sediment suspension, which causes lower light levels and possible burying of the habitats (Barbera C. et al., 2003; Duarte et al., 2004; Orth et al., 2006). Trawling has been shown to decrease the structural complexity of the habitat and can damage the root systems of seagrass and growing edges of maerl (Barbera C. et al., 2003; Duarte et al., 2004; Orth et al., 2006).

Other things that could affect these three critical habitats are frequent minor oil spills from bunkering and oilrigs, major spills from bunkering, and the enormous amount of organic matter added to the water from aquaculture pens. While untreated sewage is no longer dumped at sea, the effects from dumping raw sewage for so long may be felt for a few years in the areas where it was once pumped out. Thermal pollution from the power plant can also be detrimental to these habitats. Dumping of construction waste and the concussive explosives that are set off at the offshore firing range are also potentially damaging. It is possible to see in Map 5.3 and Map 5.4, the areas where these activities occur compared to the location of the three critical habitats. From these maps and Map 5.9, it is possible to see that Gozo and Comino are largely unaffected by most of the degrading activities with the exception of a group of aquaculture pens off of Comino's southern coast. A look at the 2006 trawl data in Map 5.2 shows that the ecosystems near Gozo and Comino would be affected by the actual trawling activities.

From Map 5.3 and Map 5.4, it is possible to see that there are substantial areas of overlap between the large maerl bed north of Malta and areas of trawling, bunkering, aquaculture, and the explosives zone. This area is also within the heavy trawling area shown in Map 5.2. The large number of detrimental activities occurring over the maerl bed has the



Map 5.3: Primary Production and Impacts in the Maltese Islands

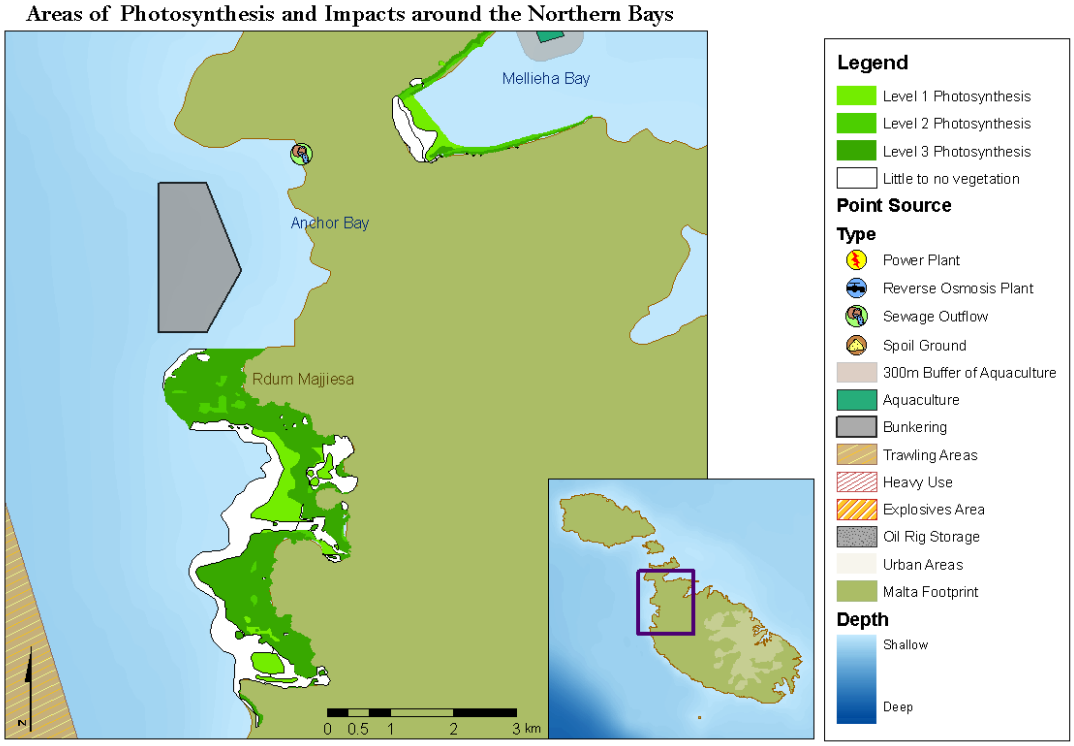


Map 5.4: Nursery habitats and impacts in the Maltese Islands

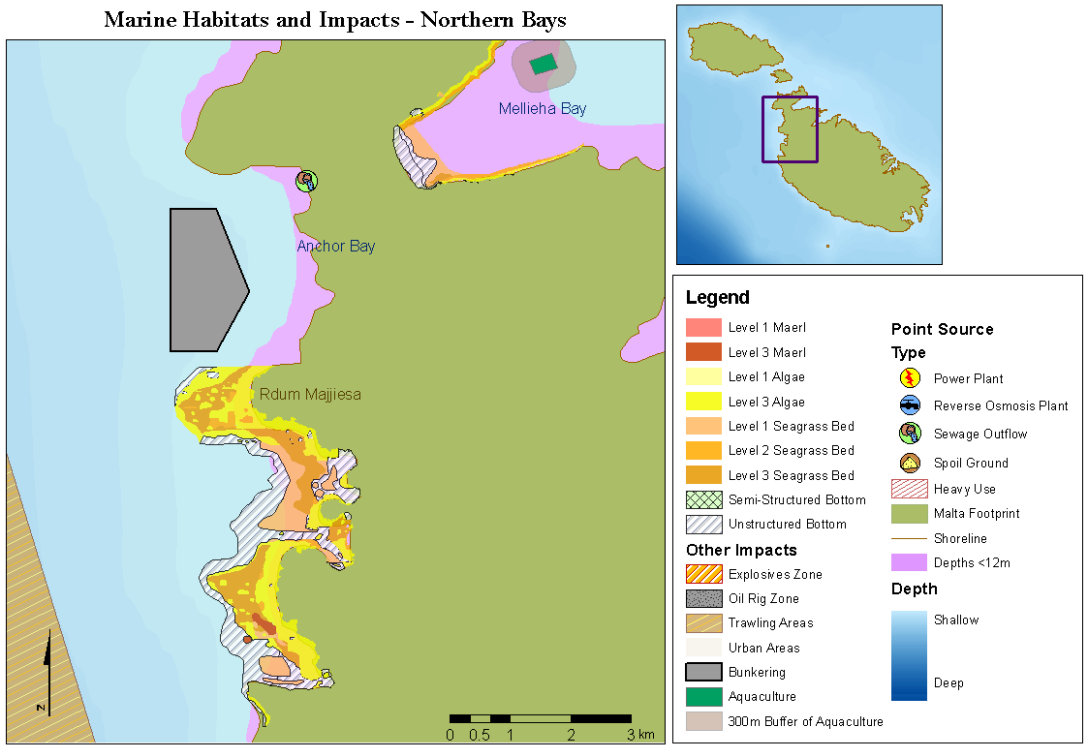
potential to degrade the habitat. This is distressing as this large maerl bed is contained within one of Malta's five MPAs (shown in Map 5.10). With a lack of any sort of regulations established for the MPAs, Malta has made no visible efforts to actually protect these "Marine Protected Areas." While enforcement of regulations at sea will always be difficult, without regulations, there cannot be anything to attempt to enforce. It appears that these MPAs were established to fulfill EU obligations rather than actually protecting the vulnerable habitat within these areas.

Maps 5.5 and 5.6 show the locations of detrimental activities in the area of the northern bays. While there is a designated trawling area nearby, the VMS data shown in Map 5.2 show that this area is not trawled frequently. A sewage outflow previously pumped raw sewage into the sea near Paradise Bay. While untreated sewage is no longer pumped, the ecosystems may have been affected by the raised levels of nutrients. It is likely that the ecosystems would feel the effects for several years after the addition of sewage has ceased. Raw sewage adds additional nutrients to the system that can reduce water quality and change the microbial community structure, degrading the ecosystems.

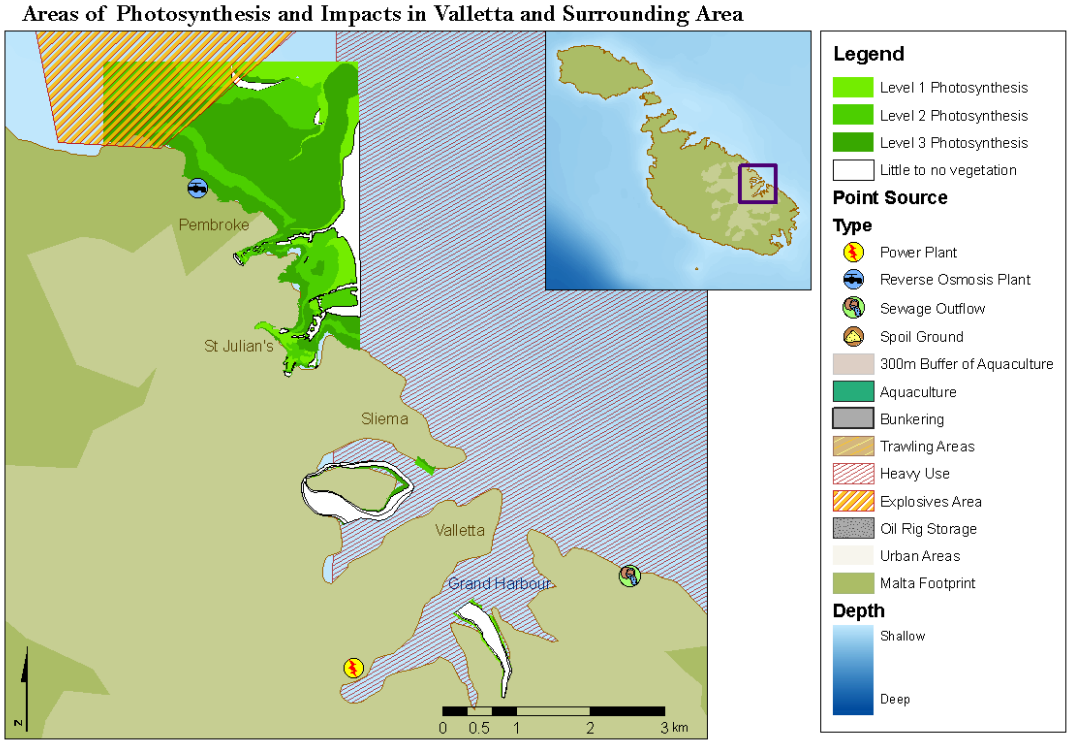
The presence of the bunkering area in Maps 5.5 and 5.6 means that there may be a continuous supply of small amounts of oil to these ecosystems. These minor spills decrease water quality and may provide the ecosystems with toxic chemicals than can be concentrated in the fauna and sediments. The presence of oil may also inhibit larval recruitment (Dicks, Hartley, Straughan, & Clark, 1982). Bunkering is also likely to affect the large maerl bed shown in Map 5.3 and 5.4, and other ecosystems further offshore that have yet to be mapped. Similar effects of the minor oil discharges from bunkering are likely to occur in ecosystems near the two commercial ports, in the Grand Harbour and the Freeport near Birzebbuga.



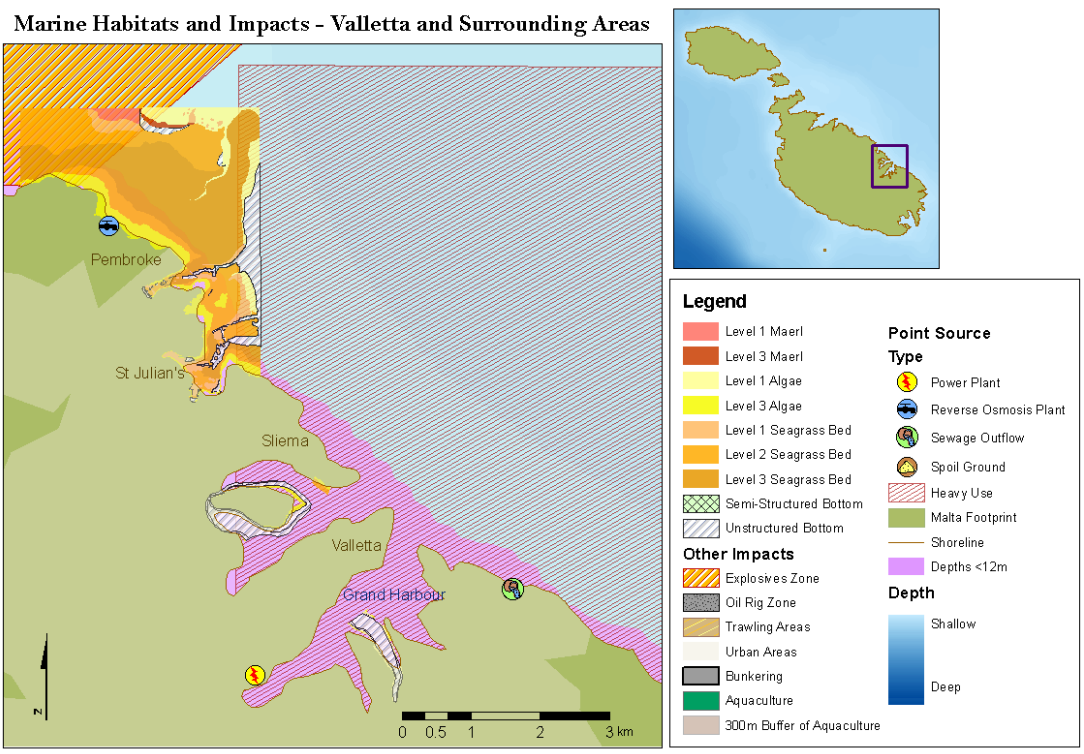
Map 5.5: Photosynthetic habitats and impacts near the Northern Bays



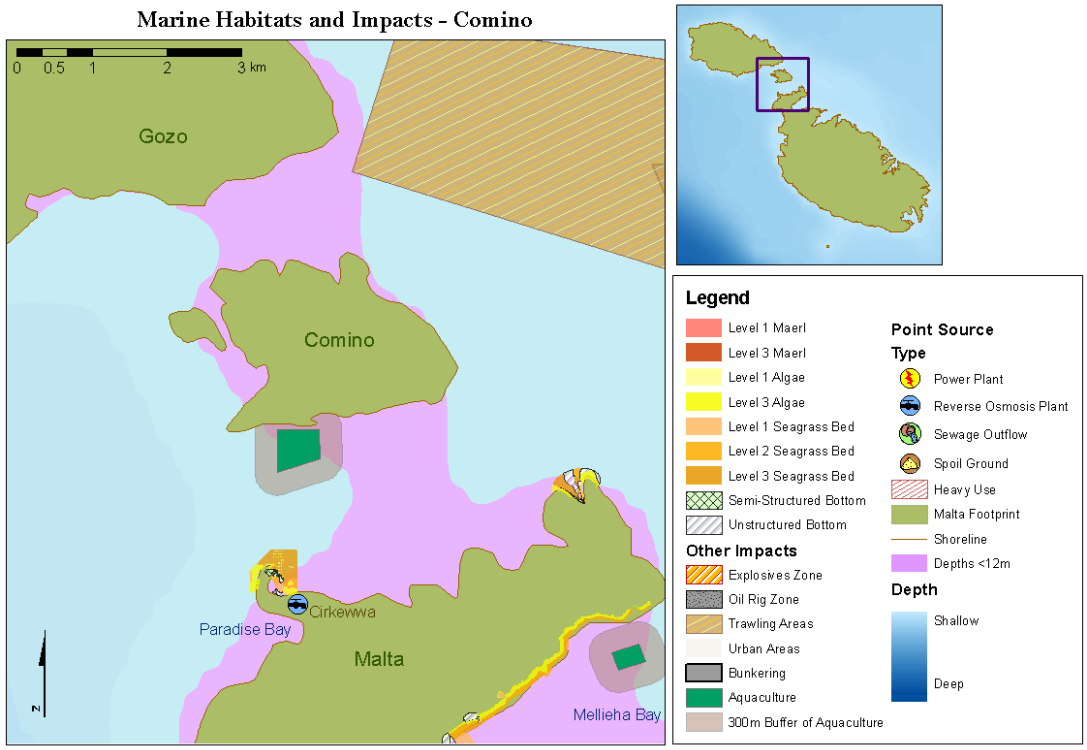
Map 5.6: Nursery habitats and impacts near the Northern Bays



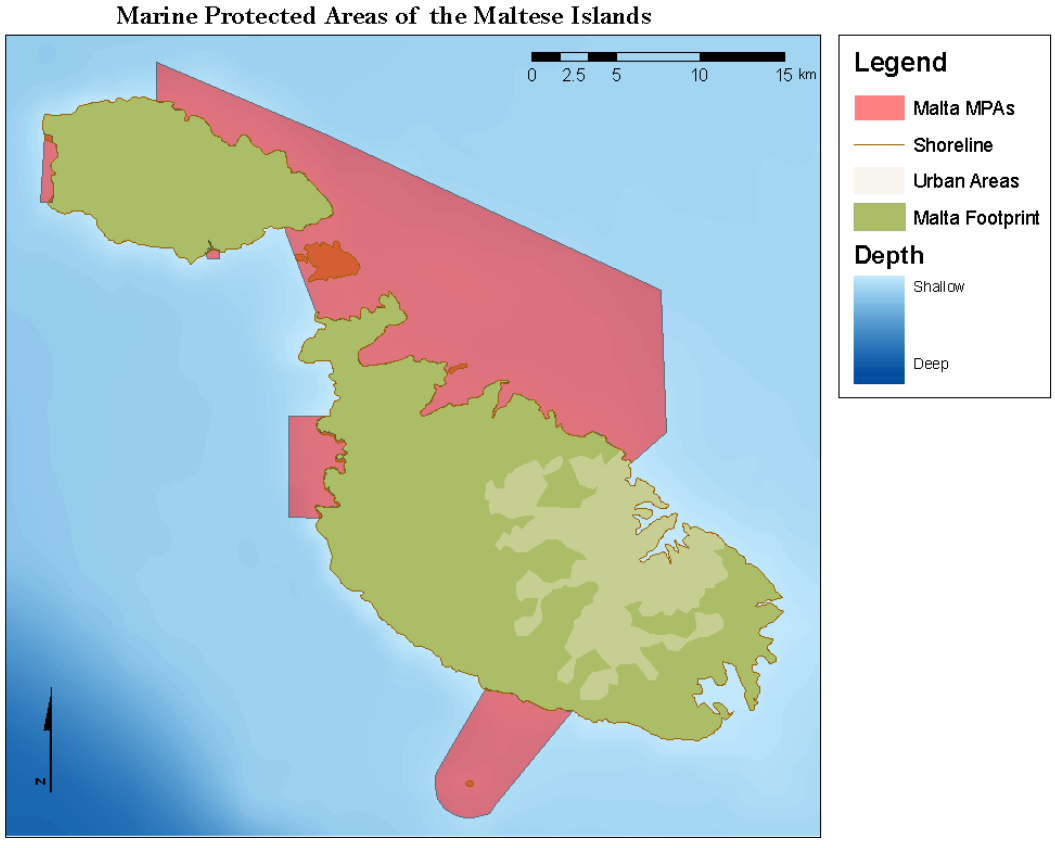
Map 5.7: Photosynthetic habitats and impacts near St Julian's Sliema and Valletta



Map 5.8: Nursery habitats and impacts near St Julian's Sliema and Valletta



Map 5.9: Nursery habitats and impacts near Comino



Map 5.10: Marine Protected Areas in Malta

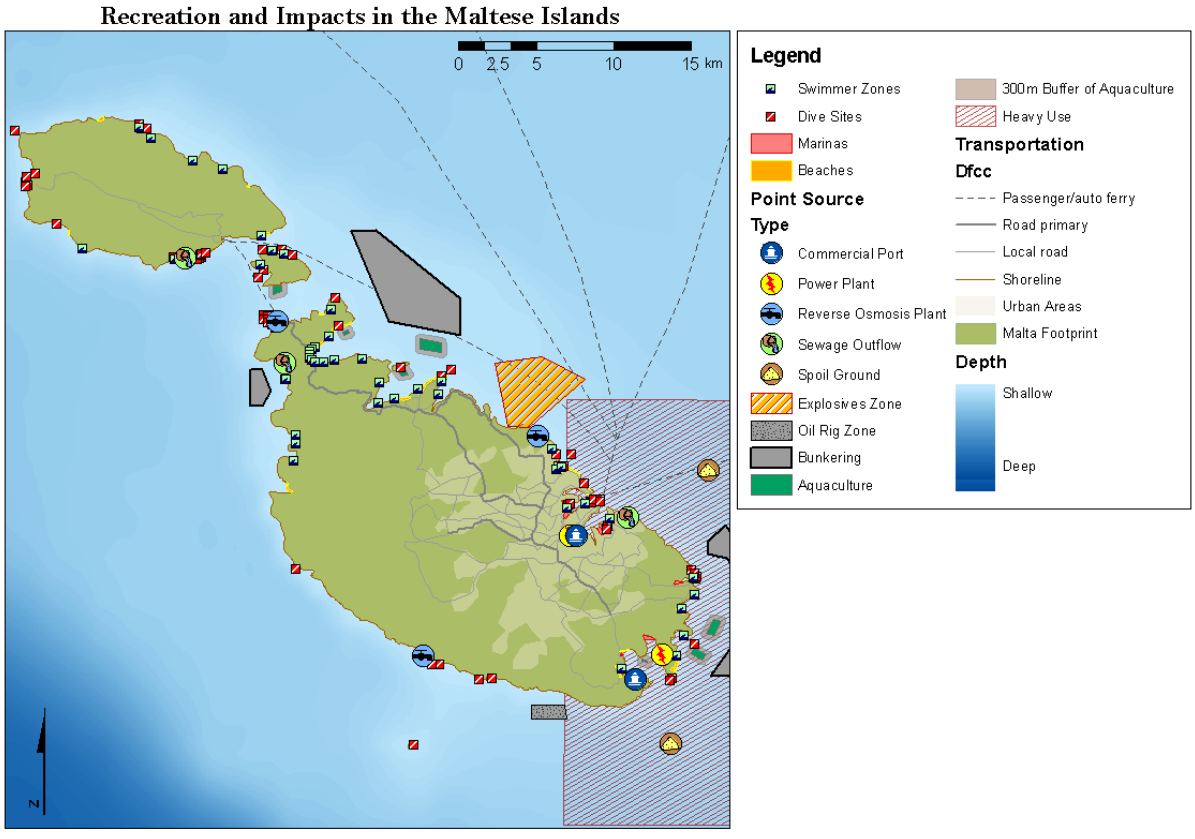
The area just north of Valletta visible in Maps 5.7 and 5.8 shows an 'Explosives Zone'. This area is used by the army for target practice for a wide range of weapons including concussive explosives. The shockwave produced by these concussive explosives hurt the swim bladders of most fish in the area, as well as damaging or destroying the habitat (McManus, 1997). This region is also affected by the area of heavy use, designating an area that sees substantial ship traffic, and points of effluent release.

The set of activities that can threaten recreational activities are different from those influencing the nursery and climate regulation services. The largest threat to tourism and recreational activities on Malta is the tourists themselves through intense tourism and recreation use. High densities of those participating in recreational activities can limit the enjoyment of the activity and damage ecosystems these activities depend upon. This means that an increase in the number of tourists, decreases in the accessibility of beaches and coastal areas due to development, and increases in commercial and recreational boat traffic all are activities that can damage the enjoyment of recreation and leisure activities. These activities are shown in the full map of Malta (Map 5.11) by areas of heavy use, locations of ferry paths and the commercial ports.

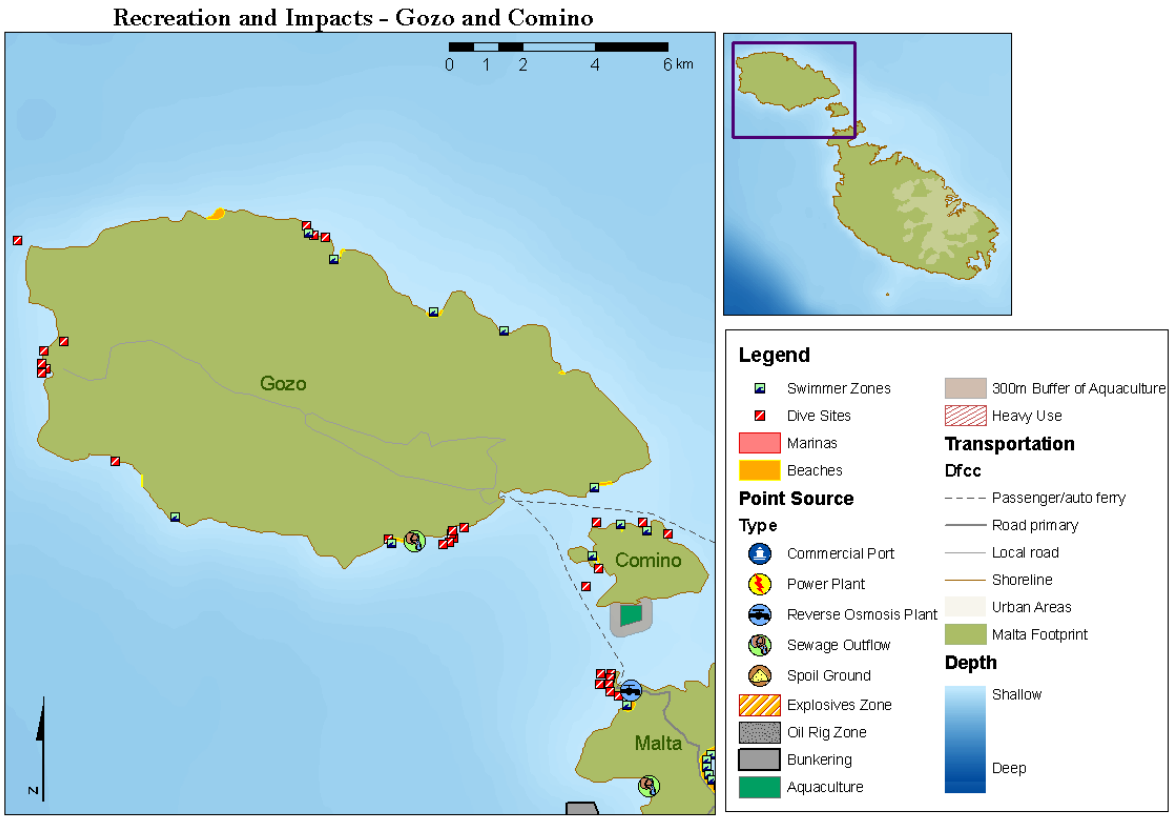
Other activities that were determined to be threats to recreation and tourism are areas of bunkering, oilrig holding areas, aquaculture, and sewage outflows. Bunkering and the oilrig holding area are threats because these activities can decrease water quality and cause a build up of oily discharges along the coast. The presence of oil slicks and on rocks was noted by several residents and tourists during the surveys for this study. While this oil may be more closely related to the maritime traffic than the presence of these bunkering areas, the threat remains. The bunkering capabilities of Malta also increase commercial traffic to Malta as in encourages ships to stop there to refuel.

Aquaculture facilities have been shown to decrease water quality, cause hypoxic dead zones below cages, decrease the density of flora and fauna, and introduce diseases and parasites into natural environments (Holmer et al., 2008; Pergent-Martini et al., 2006). These impacts have been measured as far as 300 m away from the pens, though it is suspected that impacts are felt even further (Holmer et al., 2008; Pergent-Martini et al., 2006). The resulting maps can be seen below.

Map 5.12 shows that for Gozo and Comino, the largest threats to tourism and recreation faced are those related to overuse. Raw sewage has ceased to be pumped to sea so nearby ecosystems will be facing a process of recovery and in a few years the ecosystem may revert to a lower nutrient equilibrium. The aquaculture facility is located on the side of Comino that is not used as much for recreation (though it may be that there are no dive sites



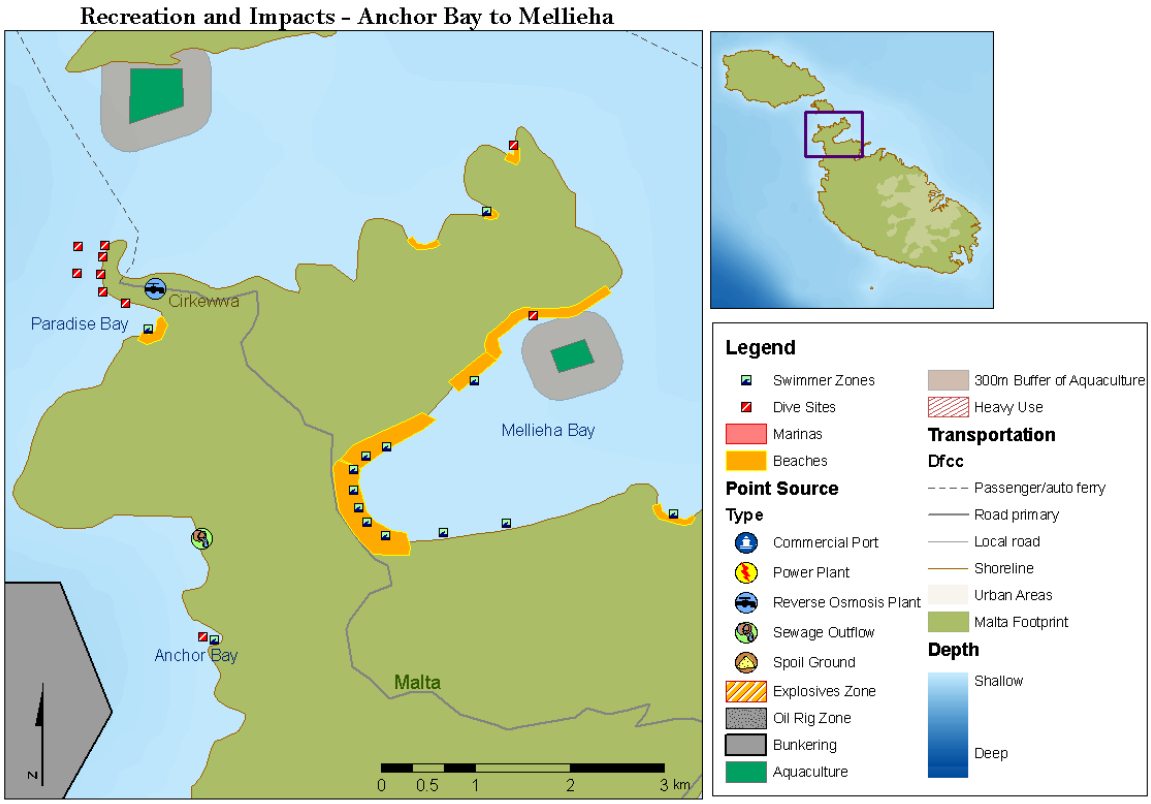
Map 5.11: Recreation and Impacts in Malta



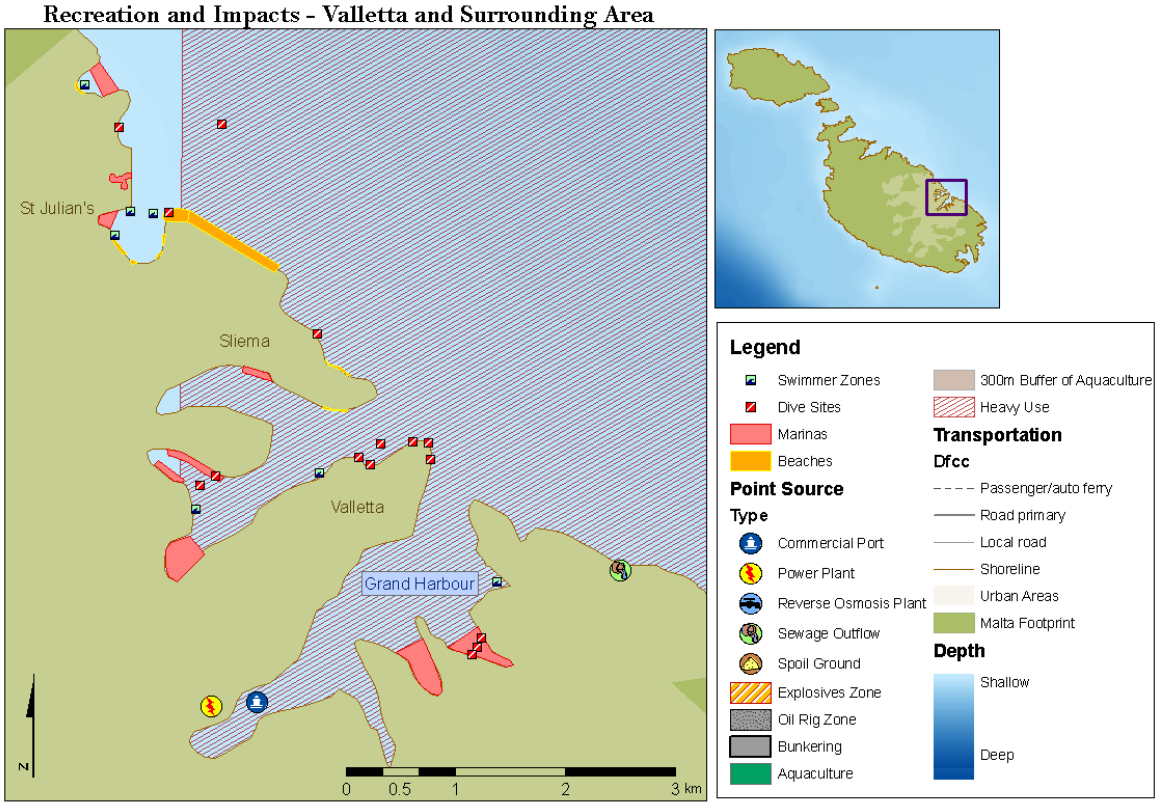
Map 5.12: Recreation and Impacts in Gozo and Comino

Map 5.13 shows the area from Anchor Bay around to Mellieha. This area has a number of dive sites and the presence of the Gozo Ferry and a number of smaller ferry services to there specifically because there is an aquaculture facility). Depending on the prevailing currents, this aquaculture site may not have a strong effect on the ecosystems necessary for recreation and tourism in Gozo and Comino.

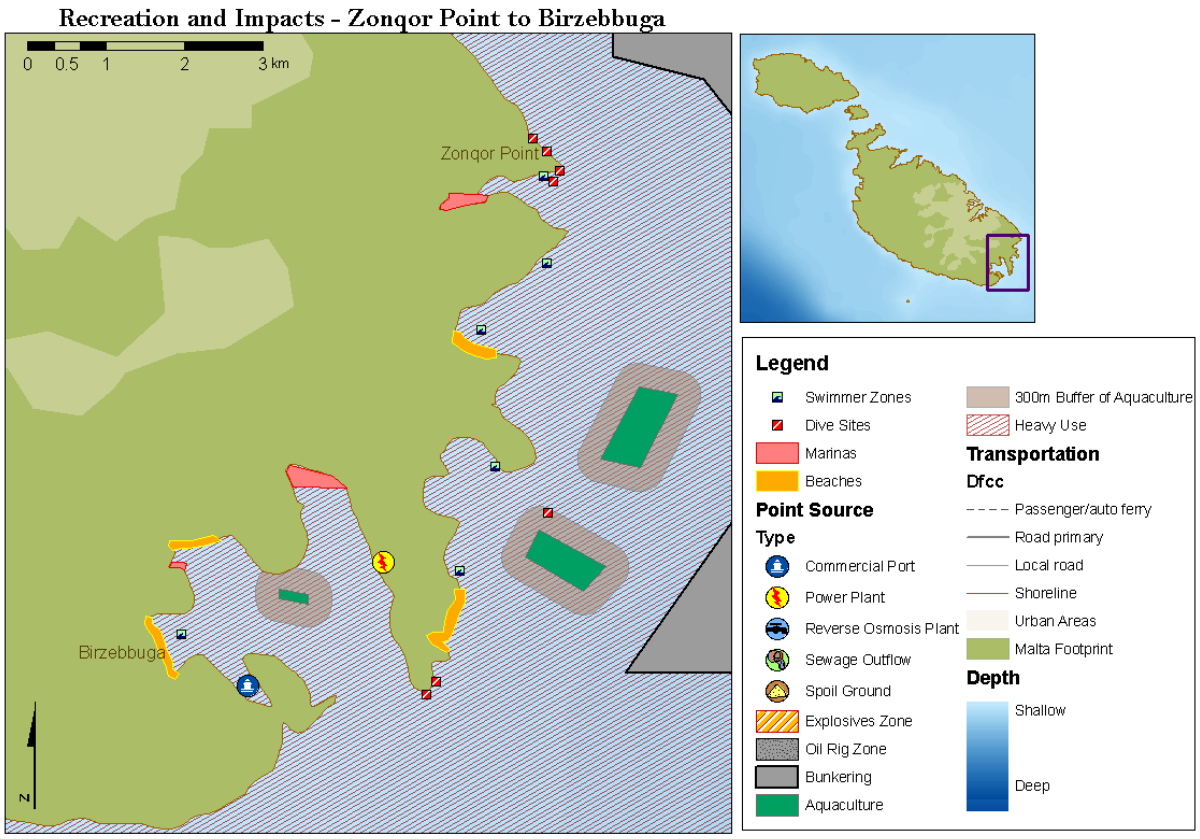
In Map 5.14 of St Julian's Sliema, Valletta, and the Grand Harbour, the most significant impacts are the result of heavy boat traffic. This area is the site of one of the two commercial ports and includes the cruise ship terminal in addition to a number of marinas. This can make accessing the dive sites and swimming outside of swimmers zones quite dangerous and less pleasant. The presence of all of these boating areas also leads to increased pollution, further decreasing the appeal of these areas.



Map 5.13: Recreation and Impacts on the Northern Tip of Malta



Map 5.14: Recreation and Impacts in St Julian's Sliema, Valletta and Surrounding Area



Map 5.15: Recreation and Impacts from Zonqor Point to Birzebbuga

4.2.5 Summary of GIS and Maps

This section demonstrates the significant amount of overlap of ecosystems that provide important services. Most ecosystems provide more than one service, however, tensions may arise because humans favor one service to the detriment of another. While this research only looks at three ecosystem services, it is likely that there are substantial overlaps with most of the marine-provided services. As an island in the middle of the Mediterranean, Malta is a hub for commercial activity. There are also huge amounts of other activities that take place on the water, largely unregulated. These activities overlap each other and important ecosystems. Malta needs to develop a plan to regulate these activities in the future and in the present. Without a plan, these activities will grow haphazardly, possibly resulting in the loss of the ecosystems and services that they provide.

5. Conclusions and Recommendations

The resident and tourist surveys collected for this research identified a number of activities as exerting significant pressures on the marine ecosystems. Many of the resident, tourist and diver views concurred with expert opinion of significant pressures. Issues such as increased coastal development, overcrowding, overfishing, increasing aquaculture facilities and GHG emissions were identified by both experts and residents as issues affecting the marine environment around Malta (Bernstein et al., 2007; Duarte et al., 2004; Hoegh-Guldberg & Bruno, 2010; Mangion, 2001; Millennium Ecosystem Assessment, 2005; Ministry of Tourism and Culture, 2007). One pressure that frequently was mentioned in the resident, tourist and diver surveys for this study, but not as frequently by experts, was the issue of waste on terrestrial coastal environments as well as within the water itself. Residents seem to be attuned to the environmental pressures facing Malta. The fact that residents seem to be as in-tune with the environmental pressures as the experts suggests that Malta would be a good place to develop a community-based management system.

While the residents and tourists may be attuned to major environmental pressures, it seems as though there is not substantial understanding of their personal role in causing these environmental pressures to exist. Survey results indicate that this may be the result of confusion over the environmental processes involved or a mental 'not my fault' attitude, or more likely, some combination of the two. The lack of comprehension among tourists of their environmental impact is likely a global phenomenon and not restricted to those visiting Malta. As tourism is one of the fastest growing industries in the world (Burgin & Hardiman, 2011; Schloegel, 2007), the confusion over the impacts of tourism by tourists could become a huge problem for Malta as well as globally.

The surveys may have been hampered by the lack of a test group or pre-survey. Such a test group may have identified some of the problems with the surveys before they were solicited. Problems with the surveys included software issues, confusing questions, and unrelated questions. At the start of the resident survey, a programming glitch made it impossible for some people to proceed beyond the activities page. While it was quickly resolved, it may have deterred several people from taking the survey. Some of the questions led to confusion among the survey respondents. For example, one question on the dive survey asked respondents to "Please rank [the following] in order of habitat preference with 1 being most preferred and 7 being least preferred." This question resulted in some respondents placing the habitats in order of preference (the intention), while other respondents used the 1-7 as a scale, giving some habitats equal values.

The surveys also suffered from a lack of focus. The surveys were designed to gain a small amount of insight into a large number of areas; they might have been better if they had gone further into depth on a few of the key topics. Formulation of the surveys was done prior to data collection for the maps, so questions were asked that ended up being irrelevant to the study because of a lack of data. For example, the dive survey included a number of questions about factors that increase enjoyment of diving, habitat preferences, and why respondents chose to dive on Malta. Initially it was thought that with the information about habitat preference, it would be possible to rank the importance of different dive sites. However, collecting data about the specific habitats and dive characteristics was not possible with this study, so the results from these questions were not used to identify the important habitats for the GIS maps.

The GIS maps for this study overlay areas of importance for particular ecosystem services with activities that could affect those services. These maps are hampered by insufficient and incomplete data. Maps, like other models, can only be as good as the data that are used to

create them. Because a complete map of habitats was not available for Maltese waters, the maps developed for this study are not sufficient to provide quality recommendations about which areas should be protected and which could be used freely. Without knowing what habitat occurs over most of the study area, it is impossible to say what areas should be considered essential habitat. Marine planning frequently is based upon data with a large degree of uncertainty; however the size of the unmapped area in relation to the areas that have been mapped makes the uncertainty in the data much too large for good decision making. Mapping more of the habitat, both on and off shore is a requirement before a management plan can be created.

The GIS maps developed for this project show evidence of two important points: i) substantial industries and activities exists that depend on and take place within the marine environments around Malta; and ii) activities frequently overlap with each other and important habitats. Evidence from the trawl VMS data compared to the designated trawling areas show that even when there are designated areas for certain activities this does not mean that these are the areas in which these activities actually occur. It is likely that even more overlap exists than the maps show. With the potential development of offshore wind or wave power, and increases in aquaculture facilities, it is likely that Malta will have more activities taking place off its shores in the future. Due to the large number of conflicting activities that occur in Malta's EEZ, marine spatial planning may be a good tool for organizing, regulating, and managing the ecosystems and activities that take place. It is up to the Maltese people and government to determine which ecosystems, industries, activities, and economic incentives are important to protect, prevent encourage or restrict in the waters around the islands. However, without a discussion of these issues, Malta runs the risk of unplanned expansion. Unplanned expansion of economic activities encourages unsustainable use of resources, stressing ecosystems and developing over the carrying capacity of an environment (Mangion, 2001).

Enforcement of laws, regulations, and policies is always a difficult process in the marine environment. However, if there are no regulations to enforce, it becomes an impossible process. While Malta has five designated Marine Protected Areas (MPA), currently none of them have regulations addressing use within the areas (Cousin). Many of these MPAs overlap with activities that are significantly harmful to the marine environment. If Malta is serious about protecting these areas, an evaluation of the habitats that exist, ecosystem services that they provide, and activities that use these areas must occur. Along with this, Malta must create regulations to prevent the degradation of these ecosystems

Marine spatial planning is a tool that can be used to plan for present and future uses of the marine environment around Malta. It allows for the incorporation of economic incentives, ecosystem services, and community involvement. Marine spatial planning advises policy makers and managers about using the environment in a way that minimizes harmful impacts. After discussions with stakeholders, areas that meet the needs of specific industries and ecosystem services are identified. GIS maps are used by communities and policy makers to identify areas of conflicting uses, and allocate areas to specific activities. Because Malta has so many activities occurring in its waters, marine spatial planning is both more difficult and more important.

This research can be a starting point for a discussion of the marine environment in Malta. Many more ecosystem services occur than just the three chosen for this research, but information can be extrapolated from the data to help facilitate discussions. For example, this research shows that the Maltese people use marine and coastal environments for a number of leisure activities. It also shows confusion may exist among the layperson about specific terms

like 'ecosystem services', and processes such as climate regulation, indicating that discussions may need to avoid using these terms or include an explanation.

The GIS maps coordinate substantial data that has been held by different agencies across Malta. The maps are a good starting point for discussions about what activities occur and where, what stakeholders will need to be consulted, and where specific ecosystems exists. While the data will need to be improved, this issues raised in this paper are a starting point for this process. The idea is to get people talking about the marine environment. Marine research and management has trailed behind terrestrial research and management largely because of the difficulty in accessing the area and the 'out of sight, out of mind' mentality of the public. While Malta may think it is progressive in its marine management, the data does not always support this. With the lack of natural resources available on Malta, the country cannot afford to ignore the marine environment for much longer.

Appendix A: IRB Proposal

Full Board	*James Madison University* **HUMAN RESEARCH REVIEW REQUEST**	*Full Board*

Investigators: This form is required for Expedited review for all JMU research involving human subjects. If you are eligible for an exemption request, please use the alternate forms at:
http://www.jmu.edu/sponsprog/irb/irbExemptionRequest.doc
http://www.jmu.edu/sponsprog/irb/irbFullBoardRequest.doc

Reviewer:

Reviewer:

FOR IRB USE ONLY:
Protocol Number: IRB- **12-0026**
Received: 1st Review: ___
2nd Review: ____ ___
3rd Review: ____ ___

☐ **Approved** Date: _____

☐ **Disapproved** Date: _____

☐ **Exempt** Date: _____

External Funding: ☐ YES X NO If YES, Sponsor(s):

Project Title: Human Perceptions and use of Maltese Marine Ecosystems

Project Dates: (Not to exceed 1 yr minus 1 day) From: 06/1/11 MM/DD/YY To: 05/31/12 MM/DD/YY

Minimum Number of Participants 200

Maximum Number of Participants 1000

Responsible Researcher(s):	Erin Reilly	**Department:**	ISAT
E-mail:	reillyem@dukes.jmu.edu	**Address (MSC):**	
Telephone:	+356 9955 3571		Not on Campus

Please select:	Visiting Faculty	Adjunct Faculty	Research Associate	Administrator/ Staff Member	Undergrad Student	Graduate Student
☐ Faculty	☐	☐	☐	☐	☐	X

(if Applicable):

Research Advisor:	Bob Kolvoord	**Department:**	ISAT
E-mail:	kolvoora@jmu.edu	**Address**	
Telephone:	+1 540 568-2752	**(MSC):**	4102

Investigator: Please respond to the questions below. The IRB will utilize your responses to evaluate your protocol submission.

1. **X YES** ☐ **NO** Does the James Madison University Institutional Review Board define the project as ***research?***

   The James Madison University IRB defines "research" as a "*systematic* investigation designed to develop or contribute to *generalizable knowledge*." All research involving human participants conducted by James Madison University faculty, staff, and students is subject to IRB review.

2. **X YES** ☐ **NO** Are the human participants in your study ***living*** individuals?

   "Individuals whose physiologic or behavioral characteristics and responses are the object of study in a research project. Under the federal regulations, human subjects are defined as: living individual(s) about whom an investigator conducting research obtains:
   (1) data through intervention or interaction with the individual; or (2) identifiable private information."

3. **X YES** ☐ **NO** Will you obtain data through ***intervention*** or ***interaction*** with these individuals?

"Intervention" includes both physical procedures by which data are gathered (*e.g.*, measurement of heart rate or venipuncture) and manipulations of the participant or the participant's environment that are performed for research purposes. "Interaction" includes communication or interpersonal contact between the investigator and participant (*e.g.*, surveying or interviewing).

4. ☐ **YES X NO** Will you obtain ***identifiable private information*** about these individuals?

"Private information" includes information about behavior that occurs in a context in which an individual can reasonably expect that no observation or recording is taking place, or information provided for specific purposes which the individual can reasonably expect will not be made public (*e.g.*, a medical record or student record). "Identifiable" means that the identity of the participant may be ascertained by the investigator or associated with the information (*e.g.*, by name, code number, pattern of answers, etc.).

5. ☐ **YES X NO** Does the study present ***more than minimal risk*** to the participants?

"Minimal risk" means that the risks of harm or discomfort anticipated in the proposed research are not greater, considering probability and magnitude, than those ordinarily encountered in daily life or during performance of routine physical or psychological examinations or tests. Note that the concept of risk goes beyond physical risk and includes psychological, emotional, or behavioral risk as well as risks to employability, economic well being, social standing, and risks of civil and criminal liability.

CERTIFICATIONS:

For James Madison University to obtain a Federal Wide Assurance (FWA) with the Office of Human Research Protection (OHRP), U.S. Department of Health & Human Services, **all** research staff working with human participants must sign this form and receive training in ethical guidelines and regulations. "Research staff" is defined as persons who have direct and substantive involvement in proposing, performing, reviewing, or reporting research and includes students fulfilling these roles as well as their faculty advisors. The Office of Sponsored Programs maintains a roster of all researchers who have completed training within the past three years.

Test module **at OSP website http://www.jmu.edu/sponsprog/irb/irbtraining.html**

Name of Researcher(s)	Training Completion Date
Erin Reilly	13 Jun 2011
Bob Kolvoord	08 Jan 2010

For additional training interests visit the National Institutes of Health Web Tutorial at:
http://cme.nci.nih.gov/

By signing below, the Responsible Researcher(s), and the Faculty Advisor (if applicable), certifies that he/she is familiar with the ethical guidelines and regulations regarding the protection of human research participants from research risks. In addition, he/she agrees to abide by all sponsor and university policies and procedures in conducting the research. He/she further certifies that he/she has completed training regarding human participant research ethics within the last three years.

_____ _____

Principal Investigator Signature Date

_____ _____

Principal Investigator Signature Date

_____ _____

Principal Investigator Signature Date

_____ _____

Principal Investigator Signature Date

_____ _____

Faculty Advisor Signature Date

Submit an electronic version of your **ENTIRE** protocol to jmu_grants@jmu.edu.
Provide a **SIGNED** hard copy of the Research Review Request Form to:
Office of Sponsored Programs, MSC 5728, James Madison Administrative Complex, Bldg #6, Suite 26

This research is for the Dual Master's ISAT/SERM Program given in conjunction with the University of Malta

Purpose and Objectives:

The purpose of this research is to explore the relationship between people and the marine environment in Malta using the ecosystem services concept as a framework. The study uses surveys to gauge human perception of the marine environment as well as GIS to map human interactions with marine ecosystems as the foundation to establish a baseline of public perception and ecosystem health as well as identify possible areas for concern in the future. The study will also make recommendations for management of marine areas around Malta.

Procedures/Research Design/Methodology/Timeframe:

Separate surveys will be done for residents, tourists and divers during the months of July and August. All participants will be at least 18 years of age and will be proficient in the English language. As English is one of the two national languages in Malta, this should not be an issue for residents. It is also not expected to be a large issue for the tourist or diver populations as a large proportion of tourists coming to Malta are from the UK or are attending English language school. Resident surveys will be conducted online using the program designed by survey gizmo (www.surveygizmo.com) with a snowball approach. This method was chosen because of limited time, funding and acquaintances known to the primary researcher. Surveying tourists is important as tourists are an important stakeholder and user of the marine environment, however, this process will be more difficult as they are a transient population. Because of this, more than one survey method will be used to obtain enough responses to be of value. Tourist surveys will be handed out on clipboards on a random basis at the airport by the primary researcher pending approval by airport staff. Additional surveys will be completed by asking hotel and tour agencies to assist in the collection by handing out and collecting surveys. Dive surveys will be handed out at dive shops by employees. Completed surveys will be placed in collection receptacles to maintain anonymity. Due to the time and resource constraints on the primary researcher, a number of operators at hotels, tour companies and dive shops have been contacted to assist with the data collection. No identifiable information will be collected so there is no discernible risk associated with this survey, even if anonymity is compromised (though it is expected that the procedures described above should attend to this concern).

Data Analysis:

Data will be stored on the Survey Gizmo server until analyzed by the researcher. Survey Gizmo's security policy can be seen at http://www.surveygizmo.com/security/. Survey

Gizmo transfers information via an Advanced Encryption Standard to a private network behind a firewall. Once collected, data will be compiled using the Survey Gizmo software as well as exported into Excel on the researcher's personal computer. During reporting, no names will be associated with any of the data collected as there will not be any identifiable information collected.

Reporting Procedures:

The data collected for this study will be used primarily for the author's Master's thesis. Data will be reported both in writing as well as in presentation form. If the data yields any significant results, data may be shared with policymakers, managers, or peer reviewed journals in writing or in a presentation setting. Subjects will not be contacted after the survey and following the completion of this study data will be deleted from the author's computer. Survey gizmo has a procedure for the deletion of data from their servers so data will not be stored anywhere once the project is completed.

Experience of the researcher (and advisor, *if student*):

The primary researcher, Erin Reilly has no prior experience with human research subjects. The advisor for this project, Dr. Bob Kolvoord has had prior experience with human research with classroom curriculum development and use of GIS technologies.

Appendix B: Full Version of the Surveys

Resident Survey
Marine Resources around Malta

Introduction and Consent
This survey is part of a Master's thesis at the University of Malta examining public perception and use of the sea around Malta. Taking the survey should take no more than 20 minutes and all responses will be anonymous. Your participation is entirely voluntary and you may withdraw at any time. By taking this survey you are agreeing to allow your responses to be used for the purpose of this research. Please do not participate if you are not a resident of Malta and at least 18 years of age. If you have any questions about your participation in this study you may e-mail erei0003@um.edu.mt. Thank you for your help!

Activities
1) Which of the following activities have you participated in on Malta? (check all that apply)
[ ] Scuba Diving
[ ] Snorkeling
[ ] Swimming from a Rocky Beach
[ ] Swimming from a Sandy Beach
[ ] Barbequing at a Rocky Beach
[ ] Barbequing at a Sandy Beach
[ ] Sunbathing at the Beach
[ ] Other Beach Activities (please specify)
[ ] Harbour Tours
[ ] Boating, Yachting, or Jet Skiing (with an engine)
[ ] Sailing, Kayaking, Canoeing, or Paddle-boating (without an engine)
[ ] Recreational Fishing from shore
[ ] Recreational Fishing from a boat
[ ] Commercial Fishing
[ ] Eating Fish or other seafood (including octopus, shrimp, mussels etc.)

When do you go scuba diving?
( ) Year Round ( ) In the summer

On average, how frequently do you go scuba diving?
( ) Everyday
( ) More than once a week
( ) Weekly
( ) Monthly
( ) Every 2-3 Months
( ) Once or Twice a Year
( ) Less than Once a Year

2) When do you go snorkeling?
( ) Year Round ( ) In the summer

3) On average, how frequently do you go snorkeling?
( ) Everyday
( ) More than once a week

( ) Weekly
( ) Monthly
( ) Every 2-3 Months
( ) Once or Twice a Year
( ) Less than Once a Year

4) When do you go swimming from a rocky beach?
( ) Year Round ( ) In the summer

5) On average, how frequently do you go swimming from a rocky beach?
( ) Everyday
( ) More than once a week
( ) Weekly
( ) Monthly
( ) Every 2-3 Months
( ) Once or Twice a Year
( ) Less than Once a Year

6) When do you go swimming from a sandy beach?
( ) Year Round ( ) In the summer

7) On average, how frequently do you go swimming from a sandy beach?
( ) Everyday
( ) More than once a week
( ) Weekly
( ) Monthly
( ) Every 2-3 Months
( ) Once or Twice a Year
( ) Less than Once a Year

8) When do you barbeque on a rocky beach?
( ) Year Round ( ) In the summer

9) On average, how frequently do you barbeque on a rocky beach?
( ) Everyday
( ) More than once a week
( ) Weekly
( ) Monthly
( ) Every 2-3 Months
( ) Once or Twice a Year
( ) Less than Once a Year

10) When do you barbeque on a sandy beach?
( ) Year Round ( ) In the summer

11) On average, how frequently do you barbeque on a sandy beach?
( ) Everyday
( ) More than once a week
( ) Weekly
( ) Monthly
( ) Every 2-3 Months

( ) Once or Twice a Year
( ) Less than Once a Year

12) When do you sunbathe at a beach?
( ) Year Round ( ) In the summer

13) On average, how frequently do you sunbathe at a beach?
( ) Everyday
( ) More than once a week
( ) Weekly
( ) Monthly
( ) Every 2-3 Months
( ) Once or Twice a Year
( ) Less than Once a Year

14) When do you go out on the sea using a boat, yacht, jet ski or other vehicle with an engine?
( ) Year Round ( ) In the summer

15) On average, how frequently do you go out on the sea using a boat, yacht, jet ski or other vehicle with an engine?
( ) Everyday
( ) More than once a week
( ) Weekly
( ) Monthly
( ) Every 2-3 Months
( ) Once or Twice a Year
( ) Less than Once a Year

16) When do you go out on the sea using a kayak, canoe, paddle boat or other vehicle without an engine?
( ) Year Round ( ) In the summer

17) On average, how frequently do you go out on the sea using a kayak, canoe, paddle boat or other vehicle without an engine?
( ) Everyday
( ) More than once a week
( ) Weekly
( ) Monthly
( ) Every 2-3 Months
( ) Once or Twice a Year
( ) Less than Once a Year

18) When do you go fishing from shore?
( ) Year Round ( ) In the summer

19) On average, how frequently do you go fishing from shore?
( ) Everyday
( ) More than once a week
( ) Weekly
( ) Monthly
( ) Every 2-3 Months

( ) Once or Twice a Year
( ) Less than Once a Year

20) When do you go fishing from a boat for fun?
( ) Year Round ( ) In the summer

21) On average, how frequently do you go fishing from a boat for fun?
( ) Everyday
( ) More than once a week
( ) Weekly
( ) Monthly
( ) Every 2-3 Months
( ) Once or Twice a Year
( ) Less than Once a Year

22) On average, how frequently do you go fishing for commercial reasons?
( ) Everyday
( ) More than once a week
( ) Weekly
( ) Monthly
( ) Every 2-3 Months
( ) Once or Twice a Year
( ) Less than Once a Year

23) On average, how frequently do you eat fish or other seafood (octopus, shrimp, mussels etc)?
( ) Everyday
( ) More than once a week
( ) Weekly
( ) Monthly
( ) Every 2-3 Months
( ) Once or Twice a Year
( ) Less than Once a Year

Ecosystem Services
24) What do you think is meant by the term "ecosystem service"?

Ecosystem Service Examples
25) Based on your previous answer, can you give some examples of an ecosystem service?

Importance
26) On a scale of 1-5 (with 1 being not important and 5 being extremely important) how would you rate the importance of the aesthetic beauty of the sea to Malta?
( ) 1 - Not at all important
( ) 2
( ) 3 - Somewhat important
( ) 4
( ) 5 - Extremely important
( ) No Opinion
( ) I don't understand

27) On a scale of 1-5 (with 1 being not important and 5 being extremely important) how would you rate the importance of tourism to Malta?
( ) 1 - Not at all important
( ) 2
( ) 3 - Somewhat important
( ) 4
( ) 5 - Extremely important
( ) No opinion
( ) I don't understand

28) On a scale of 1-5 (with 1 being not important and 5 being extremely important) how would you rate the importance of fishing to Malta?
( ) 1 - Not at all important
( ) 2
( ) 3 - Somewhat important
( ) 4
( ) 5 - Extremely important
( ) No opinion
( ) I don't understand

29) On a scale of 1-5 (with 1 being not important and 5 being extremely important) how would you rate the importance of having a predictable and consistent climate in Malta?
( ) 1 - Not at all important
( ) 2
( ) 3 - Somewhat important
( ) 4
( ) 5 - Extremely important
( ) No opinion
( ) I don't understand

30) On a scale of 1-5 (with 1 being not important and 5 being extremely important) how would you rate the importance of the sea in regulating climate?
( ) 1 - Not at all important
( ) 2
( ) 3 - Somewhat important
( ) 4
( ) 5 - Extremely important
( ) No opinion
( ) I don't understand

31) On a scale of 1-5 (with 1 being not important and 5 being extremely important) how would you rate the importance of the sea in relation to your perception of Malta?
( ) 1 - Not at all important
( ) 2
( ) 3 - Somewhat important
( ) 4
( ) 5 - Extremely important
( ) No opinion
( ) I don't understand

32) On a scale of 1-5 (with 1 being not important and 5 being extremely important) how would you rate the importance of the sea in relation to how you see yourself as a resident of Malta?
( ) 1 - Not at all important
( ) 2
( ) 3 - Somewhat important
( ) 4
( ) 5 - Extremely important
( ) No opinion
( ) I don't understand

Human Impacts
33) Do you think that human activities can have an impact on the aesthetic beauty of the sea around Malta?
( ) Yes
( ) No
( ) I don't know

Please describe what activities and impacts you think can alter the aesthetic beauty of the sea around Malta

34) Do you think that human activities can have an impact on fishing in Malta?
( ) Yes
( ) No
( ) I don't know

Please describe what activities and impacts you think can alter fishing

35) Do you think that human activities can have an impact on the abilities of the sea to moderate climate in Malta?
( ) Yes
( ) No
( ) I don't know

Please describe what activities and impacts you think can alter the ability of the sea to moderate the climate around Malta

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Changes over time
36) Have you noticed any changes to the aesthetic beauty of the Sea around Malta in your lifetime?
( ) Yes
( ) No
( ) I don't know

Please describe the changes you have observed.

37) Have you noticed any changes in the species, quantity or size of fish and other seafood caught around Malta in your lifetime?
( ) Yes
( ) No
( ) I don't know

Please describe the changes you have observed.

38) Have you noticed any changes to the climate of Malta in your lifetime?
( ) Yes
( ) No
( ) I don't know

Please describe the changes you have observed.

Demographics
39) How long have you lived in Malta?
( ) Less than 1 year
( ) 1-3 years
( ) 3-5 years
( ) 5-10 years
( ) Greater than 10 years

40) What is your Age?
( ) 18-24
( ) 25-34
( ) 35-54
( ) 55+

41) What is your gender?
( ) Male
( ) Female

42) What is your Nationality?
( ) Maltese
( ) British
( ) Other EU: _____
( ) Other: _____

43) What is your profession?
( ) Scientific Community (engineering, biology, chemistry etc.)
( ) Policy Making (Politician, Management etc)
( ) Professional (Medicine, Law, Architecture etc.)
( ) Tourism
( ) Craftsman
( ) Student
( ) Other: _____
( ) Don't work

Thank You!
Thank you for taking our survey! Your response is greatly appreciated!

Tourist Survey:

This survey is part of a Master's thesis at the University of Malta examining public perception and use of the sea around Malta. By taking this survey you are agreeing to allow your responses to be used for the purpose of this research. Please do not participate unless you are a tourist currently visiting Malta. Thank you for your help!

1. Why did you come to Malta? (*Check all that apply*)

□ Business □ Diving □ Cultural heritage □ Sun, Sea and Sand
□ Nightlife/Festival □ Relaxation □ Natural Landscape □ Language School
□ Cruise Stopover □ Other *please specify* _____

2. Which of the following activities have you done while in Malta? (*Check all that apply*)

- □ Scuba Diving
- □ Snorkeling
- □ Swimming from a rocky beach
- □ Swimming from a sandy beach
- □ Sunbathing
- □ Barbequing on a beach
- □ Harbour Cruise or Boat Tour
- □ Boating, Yachting, Jet-skiing or other water activity using an engine
- □ Sailing, Kayaking, Paddle boating or other water activity without an engine
- □ Recreational Fishing
- □ Eating fish or other seafood
- □ Other water related activities (*Please specify)* _____

3. Please rank how you think your activities compare to those of a resident:

	Much less than residents	Somewhat less than residents	The same as residents	Somewhat more than residents	Much more than residents
Water Use	1	2	3	4	5
Electricity Use	1	2	3	4	5
Waste Production	1	2	3	4	5
Transport emissions	1	2	3	4	5
Use of the Ocean	1	2	3	4	5
Consumption of Seafood	1	2	3	4	5

4. If you were informed that tourism was causing significant harm to the marine environments around Malta would you be willing to? (*Please check all that apply*)

- □ Pay a tourism fee upon entering the country
- □ Pay a small additional fee for any water related activities in which you participate
- □ Stay at an ecofriendly hotel that might restrict some services
- □ Stay at a hotel certified as a “green” hotel
- □ Have to book water related activities in advance due to restrictions of visitor numbers

5. Are you likely to return to Malta?
□ Yes, Definitely □ I'd like to □ Probably not □ Definitely not

6. Would you be more

	Much less likely to return	Somewhat less likely to return	Just as likely to return	Somewhat more likely to return	Much more likely to return
There was less seafood available	1	2	3	4	5
There was increased waste on beaches and in the water	1	2	3	4	5
Beauty of marine landscapes declined	1	2	3	4	5
Water clarity decreased	1	2	3	4	5
There were fewer species of fish near the coast	1	2	3	4	5
The weather was Warmer	1	2	3	4	5
There were more Marine Protected Areas	1	2	3	4	5

7. *If you did not go Diving on Malta skip to question 9.* Why did you dive on Malta?

8. Please describe your experience diving here in Malta:

9. If you have been to Malta before, have you noticed any changes to the marine environments? Please describe the changes including the time over which you noticed.

10. What nationality are you? _____

11. What is your gender? Male Female

12. What is your age?
18-24 25-35 36-50 51-65 Over 65

13. What is your profession? _____

Diver Survey:

This survey is part of a Master's thesis at the University of Malta examining public perception and use of the sea around Malta. By taking this survey you are agreeing to allow your responses to be used for the purpose of this research. Please do not participate unless you are a certified SCUBA diver that has been diving in Malta. Thank you for your help!

1. Why do you choose to dive in Malta compared to other places?

2. How often do you go diving
In Malta?

In the Mediterranean?

In the world?

3. Please rank in order of habitat preference with 1 being most preferred and 7 being least preferred.

_____ Wrecks
_____ Interesting rock formations (swim-throughs, arches etc.)
_____ Seagrass beds
_____ Rocky algal reefs
_____ Sandy bottoms
_____ Caverns and caves
_____ Drop-offs

4. When choosing a dive site what factors are the most important to you? Please rank from 1 to 10 with 1 being most important and 10 being the least important

_____ Water Clarity
_____ Large number of different species
_____ Interesting underwater landscape
_____ Intentionally placed statues, chains, plaques or other human elements
_____ Water temperature
_____ Wherever the dive company takes me
_____ Presence or Absence of currents
_____ Depth of the dive
_____ Fish abundance
_____ Fish diversity

5. How does diving in Malta compare to diving in other locations?

6. Are you aware that Malta has 4 Marine Protected Areas? Yes No

7. How often do you notice other divers causing harm to the marine ecosystem?

8. Have you been diving on Malta before this trip? Yes No

If no please skip to Question 11

9. Since you have been diving on Malta have you noticed any changes in:

Range or extent of ecosystems Yes No

Types, number or size of species Yes No

Amount or extent of trash Yes No

Amount or extent of other pollution Yes No

Water Clarity Yes No

10. If you answered Yes to any of the above questions, could you please describe the changes you have observed and the timeframe over which they occurred?

11. How long have you been diving on Malta (this trip or overall)?

12. Is there anything that would make you stop diving on Malta?

13. How many years have you been diving?

14. What nationality are you? _____

15. What is your gender? Male Female

16. What is your age?
18-24 25-35 36-50 51-65 Over 65

17. What is your profession? _____

Appendix C: Sources for Maltese commercial fish nursery habitats table

#	Source
1	(Froese & Pauly, 2011)
2	(Fortibuoni et al., 2010; 2010)
3	(McMillan & Morse, 1999)
4	(Letourneur, Ruitton, & Sartoretto, 2003)
5	(Domokos, Seki, Polovina, & Hawn, 2007)
6	(Walker, Howlett, & Millner, 1997)
7	(Mather, 1994)
8	(R. A. Martin, November 2000)
9	(Maynou, Lleonart, & Cartes, 2003)
10	(Colloca, Cardinale, Belluscio, & Ardizzone, 2003)
11	(Ordines, Quetglas, Massutí, & Moranta, 2009)
12	(García-Rubies & Macpherson, 1995)
13	(S. Bussotti & Guidetti, 2011)
14	(Harmelin-Vivien et al., 1995)
15	(Deudero & Morales-Nin, 2001)
16	(Augustyn, Lipinski, & Sauer, 1992)
17	(Nixon & Mangold, 1998)
18	(Mesa, Arneri, Caputo, & Iglesias, 2005)
19	(Morales-Nin & Moranta, 1997)

Appendix D: Data Dictionary for GIS Maps

Layer Name	Shows	Created by	Source
12_nm_Sovereign_waters	Extent of Malta's Sovereign Waters, 12 nm from the coast	Reilly, Erin	Created from Malta footprint
Aquaculture	Aquaculture Pens	Reilly, Erin	Joe Bianco, Transport Malta
Bathy	Bathymetric Data, highlights depths shallower than 12m	Reilly, Erin	Created from the Depth Layer
Beaches	Popular Sand and Rock Beaches	Reilly, Erin	VisitMalta.com
Bunkering	Bunkering Sites	Reilly, Erin	Joe Bianco, Transport Malta
Depth	Bathymetric Data	ESRI	SeaWiFS Satellite Data
Depth Points	Depths at specific points	ESRI, Reilly, Erin	Created from Depth
Dive Sites	Wrecks, shore dive entry spots, boat dive areas	Reilly, Erin	Lemon (2008) Dive sites of Malta Gozo and Comino, visitMalta.com, and Dive Systems brochure
EEZ	Extent of Malta's EEZ, 25 nm from the coast	Reilly, Erin	Created from Malta footprint
Heavy Use	Areas of Heavy ship traffic	Reilly, Erin	Joe Bianco, Transport Malta
Marinas	Areas of recreational boat docking	Reilly, Erin	Google Earth
Marine_Habitats WGS84Zone33N_Climate	Habitats by level of photosynthesis/carbon sequestration	MEPA; Reilly, Erin	Created from MEPA (2003) Marine Habitat of the Maltese Islands
Marine_Habitats WGS84Zone33N_Coded	Habitats by type	MEPA; Reilly, Erin	Created from MEPA (2003) Marine Habitat of the Maltese Islands
Misc Other	Explosives Zone and Oil Rig zone	Reilly, Erin	Joe Bianco, Transport Malta
Point Source	Commercial Ports Power plants, RO, and Sewage outflow	Reilly, Erin	Water Services Corporation, Google Maps
Restricted Use Zones	Areas where certain activities such as fishing or boating are prohibited or restricted	Reilly, Erin	Joe Bianco, Transport Malta
Roads_wm	Major roads and Ferry routes	ESRI, Reilly, Erin	ESRI
Shoreline	Shoreline of the Maltese Islands	ESRI	ESRI
Swimmer Zones	Swimmer Zones	Reilly, Erin	Transport Malta
Trawling Areas	Areas where trawling is allowed	Reilly, Erin	EC 813/2004
Urban Areas	Areas of Urban Land use	ESRI	ESRI
Wreck Conservation Zones	No fishing areas around Wrecks	Reilly, Erin	Malta Maritime Authority Notice to Mariners No 5 of 2008
MPA	Marine Protected Areas	Reilly, Erin	General Notice Number 851

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