Deep Maps Cork:

Coastal Marine Influences on the Communities of South West Cork.

Literature Review.

Seán MacGabhann

2016

UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Table of Contents

Glossary of Terms

Term	Definition
Accretion	Accumulation of sand or small rocks
Acidification	The downscale driving of pH towards 1
Anoxic	Abnormally low levels of oxygen
Anthropogenic	Human influenced/ driven
Aquaculture	Human driven breeding/cultivation of aquatic organisms for commercial purposes
Baleen whales	Whales that have plates of bone, known as baleen, in the mouth for straining plankton from the water
Ballast	Material placed in the hull of the ship to aid with stability. Water is commonly used
Benthic	Organisms living on or within seafloor sediments
Biofouling	The attachment of living organisms to manmade structures
Biomass	The total quantity or weight of organisms in a given area or volume
Bycatch	The unwanted fish and other marine organisms trapped by commercial fishing nets during fishing for a different species
Catch	Fisheries terms referring to both target and non-target species hauled aboard a vessel
Cetaceans	Order comprised of whales, dolphins and porpoises
CFP	Common Fisheries Policy
Copepod	Class of small or microscopic aquatic crustaceans
DDT	A synthetic insecticide, banned in many countries today (dichlorodiphenyltrichloroethane)
Demersal	Organisms (predominantly finfish) that live close to the seafloor
Detritivore	Organisms that feed on dead organic matter E.g. Dead animals or plants
Displacement	When one species outcompetes another for resources and habitat space
Eutrophication	Raising of nutrient levels within a body of water

Feminisation	Forced transition of male to female
Hybridisation	The breeding of two varieties of organisms to produce offspring known as hybrids
Landings	The fish caught that are actually brought to shore
Mariculture	Aquaculture specifically of marine organisms
MSFD	Marine Strategy Frameworks Directive
Non-target	Species not specifically targeted as a component of the catch; may be incidentally captured as part of the targeted catch
NPWS	National Parks and Wildlife Services
Ocean productivity	Generation of biomass by marine organisms
Offshore	Situated at sea, far from the shore
Onshore	Situated on land
pH	Scale for measuring the acidity or alkalinity of a substance, with 1 being the most acidic and 14 the most alkaline.
Pinnipeds	Order comprised of seals and walrus
Predation	The feeding of one animal upon another
Sessile	Non-mobile organisms
Substratum	An underlying layer , particularly a layer of rock or sediment beneath the surface of the ground
TBT	A now banned, synthetic chemical used to prevent biofouling (Tributyl tin)
Turbidity	Cloudiness/haziness of water due to suspended particles
WFD	Water Frameworks Directive
Whitefish	Refers to several species of demersal finfish. E.g. Cod, Herring, Whiting, Hake, and Haddock

Introduction

Globally, coastal areas occupy 20% of the earth's surface, yet are home to over 50% of the human race (Cummins *et al.,* 2003). The coastal marine environment is one of the most biologically diverse and resource rich environments on the planet, and so have been utilised by people throughout history. Today coastal areas support a whole range of industries including fishing and aquaculture, shipping, leisure, transport, and pharmaceutical production, to name but a few. With over 53% of Irish people living in coastal areas (Devoy, 2011), these resources represent a significant form of livelihood and income that have been consistently present for generations. South West Cork, in particular, is known to have a long standing reliance on the marine environment for the continued survival of the many communities along its coastline. However, in recent decades, through economic and political compromise over coastal marine resources, the marine environment is being placed under new and increasing pressures. Global population increase, combined with mismanagement and over exploitation, is not only threatening the marine ecosystem, but also the people who rely upon it.

Human activity is, both directly and indirectly, imposing many of these pressures, which are affecting the coastal marine environment, on a long and short term basis, at local and global scales. Most of these issues stem from four major sources: the overexploitation of fish stocks, the expansion of the aquaculture industry, anthropogenically sourced pollution, and the increasingly volatile changes in climate patterns. This has created a need for conservation efforts to be made by government bodies, the scientific community, and the general public which has led to the establishment of many environmentally focused policies and legislations, specifically relating to the marine environment, both in Ireland and around the world. In this report, the many factors of these major sources of pressure are described, along with the importance of conservation driven policy, and how they are operating today for the people of South West Cork.

1) Fishing and Aquaculture

i) Fisheries

Human beings have always had a culture of fishing. Be it on a recreational level or industrial, people have always relied on the marine environment as a source of food. However, with global populations growing at rate expected to reach 9 billion by the year 2050 (Alexandratos and Bruinsma, 2012), the sustainability of these practices has been drawn into question. Seafood, be it shellfish or finfish, provides the human race with our most diverse source of protein (Naylor *et al.,* 2000), with the industry being thought to reach its peak in the 1990's, at 90 million tonnes per annum (Watson *et al.*, 2001). This pressure has been brought about by industrial activity and lack of proper biological knowledge, as well as from open access fisheries and poorly defined limits. In an Irish context, this can be seen by the use of Irish waters by Spanish fishermen dating back as early as the 1500's (www1) and more recently the European "super trawlers" utilising Irish waters in November of 2015. Globally, over 80% of all commercial fish stocks have been defined as being overfished, depleted, or recovering by the United Nations (2010), and are a direct result of an increase in the level of fishing. This increase began with the advancement of fishing gear after the Second World War (Pauly *et al.*, 2002), which has been continually advancing well into the 21st century. This fact has been realised by many of the world governing bodies, including the Irish Department of Agriculture and Fisheries, and so many restrictions have been placed upon the fishing industry in recent years. These restrictions include, quotas and total allowable catch (TAC), discard bans, the introduction of fisheries observers, loss and damage of gear, and even the decommissioning of fishing vessels. With the need now to fish at maximum sustainable yield (MSY), in order to maintain both a biological and economic level of sustainability, this has added additional pressures to Irish fishermen, and therefore upon the coastal communities who rely upon them.

Quotas and TAC, have been instrumental in fishery recovery since their inception by the EU in 1976 and are a major point within the Common Fisheries Policy (CFP). The purpose of these quotas are to limit the weight of catch of particular species that are permitted to be taken from designated waters. For example, in Ireland, in 2016, the national TAC for cod was 880 tonnes (wwwSFPA). This procedure is considered to be

the corner stone of fisheries conservation, and encompasses equipment usage, time spent fishing, and fishing area restrictions (Karagiannakos, 1996), and are updated annually based on the findings of Scientific and Technical Committee for Fisheries, as part of Article 12 of EU regulation 170/83 (Council of the European Communities Regulation, 1986). The quotas themselves are based on 3 factors that must be taken into account for each member state, including Ireland. These factors are:

- Traditional Fishing Practices of the Community Fleet
- Certain preferences (referred to as “the Hague preferences”) are to be applied to fishermen in areas where there is limited alternative forms of employment.
- The financial losses of Member State fishing vessels after the introduction of Economic Exclusive Zones (EEZ - a 200 nautical mile area surrounding a country’s coastline, to which said country has exclusive rights to all marine resources within (UN, 1986)) by the United Nations.

If a quota for a particular species is reached in a particular area before the year has ended, this area is “closed” to fishing, until the new quota for that area has been established for the following year. In 2015, this occurred for 10 species in areas affecting the fishing ports of Castletownbere, Baltimore, Schull and Union Hall (www2SFPA). From a biological standpoint, these quotas and closures, can allow fish stocks the time to replenish their numbers to higher levels, but economically they can cost thousands of euro annually to the income of those who rely upon these species.

Another aspect of the CFP is that of the discard ban. This restriction on commercial fishing was added to the new CFP in 2014, and forces fishermen to land every individual fish caught as part of their TAC, also known as a landing obligation (EU, 2013). This regulation came into action from January 1st 2015 for demersal fisheries and is aimed to be in effect for all fisheries from 2019. Prior to this, fishermen were permitted to discard any non-target species caught, as well as individuals of target species deemed to not be commercially valuable, such as being below a desired size or weight. Many discarded species have been shown to have high mortality post catch, therefore, despite not being a direct target of the fishing industry these species have suffered population decline (Evan *et al.,* 1994). Before this restriction came into play, up to one third of all catches were returned to the sea as discards in trawl fisheries

alone (Alverson *et al.,* 1994; Borges *et al.,* 2005). Failure to adhere to this regulation, can result in hefty fines, as well as court appearances and loss of fishing licences. This has created a call for increase in quotas to prevent major income losses for fishery dependent businesses (Cosgrove *et al.,* 2015). It has yet to be seen what the true effect of this ban has been having on Irish fisheries, but pilot studies carried out have shown that the discard ban combined with use of target specific fishing gear can help reduce any potential economic loss brought about by this restriction (Cosgrove *et al.,* 2015). However, this regulation can be difficult to monitor, as it is impossible to know at port if landings are in fact what was caught, or if discarding has occurred further out to sea. It is for this reason that fisheries observers have been employed to monitor exactly what is being caught aboard Irish fishing vessels.

In most countries, including Ireland, fisheries observers have a dual role in that of monitoring adherence to regulations, but also in scientific data gathering (Furlong and Martin, 2000). Although, not directly enforcing the law aboard vessels, it has been proven that the maintenance of an on-ship log book can deter under-reporting of landings by fishermen, while maintaining the personal safety of these non-crew members (Warner, 2004; Van Atten, 2007). It has been argued that using observers as direct enforcement officers could pose a serious danger from “resentful crew members” (Porter, 2009), and so their use as a monitoring tool is what is utilised in many nations. As part of their duties, observers will also report on any bycatch species landed by the vessel.

Bycatch is defined as “*the incidental take of undesirable size or age classes of the target species (e.g. juveniles or large females), or to the incidental take of other non-target species. Individuals caught as bycatch can be unharmed, released with injuries, or killed*” (Lewison *et al*., 2004). This applies not only to non-target, commercially worthless, fish species, but also to marine mammals, turtles, sharks, invertebrates, and sea birds. Both biological and economic issues arise from the issue of bycatch. From an economic standpoint, bycatch increases costs leaving revenues steady, while for fisheries, bad image is generated thus incurring limitations and further restriction pressures, on an industry that is already under strain. Protected species, such as cetaceans and pinnipeds, raise further issues, as these animals have been placed under the Habitats Directive of the EU (Hall *et al*., 2000). As such, their habitats and

resources are kept under a strict legislative protection and any accidental mortality must be reported to the authorities (Evans and Roma, 2006). Seals in particular have been shown to be particularly vulnerable to becoming entangled in nets. A study carried out in the South West of Ireland (Cosgrove *et al.,* 2013) observed 68 individual seals (from 2 species) bycaught in gill, trammel, and tangle nets between two vessels, over the course of a single year. This same study found 2 dolphin and 1 whale species as bycatch, with tangle nets having the highest affinity for accidental mortality. It is not just these static gear types that are a danger for these animals; long lines pose a particular threat to seabirds (Løkkeborg, 1998), while bottom trawling can cause extensive damage to benthic creatures, such as corals, sea pens, and crustaceans, through direct physical damage or smothering due to resuspension of sediments (Althaus *et al.,* 2009). Mitigation of this issue has been brought about by the use of selective gear usage. Net mesh sizes are being altered to allow smaller fish to avoid capture, “dolphin gates” are left in nets for larger animals to escape, the use of streamers on long lines have greatly reduced the number of sea bird bycatch incidents, and the banning of bottom trawling in particular areas, have all been shown to have positive effects in the reduction of accidental catch of non-target species (Ball *et al., 2000*; Løkkeborg *et al.,* 2002; Rogan and Mackey, 2007). These further limitations can, again, be costly to the fishing industry, many of whom are already under serious pressures from the previously mentioned issues.

Another factor that is proving financially costly to fishermen and a danger to the marine environment is loss of or damage to fishing gear, which can lead to ghost fishing. “Ghost fishing” can be defined as the capture of any marine organism once control of the gear has been lost by the fisherman (Brown and Macfayden, 2007). According to the FAO (Macfayden *et al.*, 2009) adverse weather, operational fishing factors (*e.g.* the cost of gear retrieval), illegal, unregulated and unreported (IUU) fishing, vandalism/theft, and access to, and, cost and availability of onshore collection facilities are all factors in the loss and damage of fishing gear. In this comprehensive report, they go on to mention that gillnets and pots/traps are most likely to “ghost fish” while other gear, such as trawls and longlines, are more likely to cause entanglement, and habitat damage. This means that lost nets or traps can continue to catch and kill a wide range of marine life. Incidents of ghost fishing in Irish waters are relatively low due to disciplined maintenance of gear by Irish fishermen (Brown and Macfayden,

2007). However, there have been reports of damage being done to nets, particularly by seals, which can put further financial pressures on the Irish commercial fishing industry (Cronin *et al.,* 2014).

With so many pressures on the fishing industry, be it biological or legislative, it is no wonder that many fishermen seek out alternative forms of employment. This is where the Decommissioning Schemes come into force. In 2005, the Department of Agriculture, Food and the Marine introduced financial incentives for fishermen to voluntarily decommission their vessels (DAFM, 2011). Primarily aimed at whitefish fishery vessels older than 15 years and greater than 18m, where upgrading of equipment to adhere to the new legislation was proving too costly, €11.8 million was allocated as reimbursement for participation in this scheme. In this initial scheme 25 of the 1,861 Irish vessels were removed from service, giving the crew of said vessels enough financial support to seek further training in a new field. In 2008, a second scheme was launched with a budget of €36.6 million, allowing for a further 46 of 2,022 vessels to be decommissioned. This second scheme included 1 vessel from Union Hall, 3 from Castletownbere, and 3 from Schull. Similar schemes were carried out with great success in other European nations such as the United Kingdom, France and Denmark. These decommissions allow ships that remain in service to fish a higher quota without exceeding national TAC, thus making the endeavour more fiscally valuable to those reliant upon the industry. The removal of these ships from service, despite the cost of public funds, is hoped to help alleviate the biological pressures of commercial fishing the world's oceans.

ii) Aquaculture

With the growing pressures on the global fisheries to provide more and more product than is readily available, the aquaculture or mariculture industry has become more and more prominent in recent years. Between 2002 and 2012, the farming of finfish and shellfish has been expanding at a rate of 6.1% annually, with the global industry having an estimated value of $137.7 billion (FAO, 2012). The Irish industry alone accounts for €115 million as of 2014 (BIM, 2014). This increase allows for human demand not to be limited by ocean productivity. However, there are many constraints placed upon aquaculture that can become issues for the coastal communities involved in

aquaculture production. These constraints include: space, complexity of life-cycles, disease, and environmental impacts.

The major constraint facing the development of the aquaculture industry at present is the need for space. Marine organisms require the water in which they live to have the proper physical and chemical parameters to yield large, healthy individuals. Such conditions are very difficult to maintain in ponds or tanks due to the requirement for complex water treatment systems and filtering devices to remove potentially toxic materials and natural wastes. Most attempts to raise marine organisms on a large scale involve significant economic investment to maintain water quality. For example, in Co. Cork, the largest finfish species to be farmed is salmon, with 3,467 tonnes produced annually (BIM, 2014). This demands for a high usage of physical space, be it in cages, tanks or ponds, where regulations and biological information, constrains the number of individual fish per until area, in order to produce commercially viable product (Theodouru, 2002).

The second major constraint effecting the aquaculture industry is the understanding of the life-cycles and processes of the organisms in question. Many marine organisms go through a complex series of larval stages, each requiring different surrounding conditions and food requirements prior to reaching marketable size. To rear each form successfully is often costly, challenging and even not currently possible in captivity. This has led to the importing of young fish into the aquaculture industry, which brings with it, its own potential dangers. This introduction of “foreign” individuals is seen to be one of the primary threats to native biodiversity around the world (Bax et al., 2003; Minchin, 2007). Invasive species can take the form of microbial life, fish pathogens, juvenile invertebrates, molluscs, crustaceans, and fish, each of which is capable of creating immense damage through biofouling cages and other structures. With the developing understanding, stemming from scientific research, these risks are being minimised, but are still a long way off from being totally closed cycles with the aquaculture industry.

Thirdly, comes the spread of disease within an aquaculture facility. Pathogens can be introduced from natural sources or through the introduction of new individuals to farm stocks. These animals have also been known to escape, spreading disease to wild

populations. When animals are confined to a relatively small space, it is common for diseases and parasites to proliferate and spread rapidly. In Irish salmon farms, outbreaks of amoebic gill disease have become more and more frequent in recent years (Palmer *et al.*, 1997). This disease attacks the gills of the fish, eventually drowning them, and has led to mass mortality across the industry (Ruane and Jones, 2013). Influence of pathogen spread is also seen in the culture of the Pacific oyster in Co. Cork. This species has shown an increase in production (7%) since 2014 (BIM, 2014), but has the potential to crash due to the spread of disease, which has been shown to give rise to mass mortalities across the UK, France, Spain and Ireland (EFSA, 2009). Financial losses due to these mortalities can have profound effects on the dozens of aquaculture employees in Co. Cork alone, not to mention the value of the product to the Irish economy as a whole.

Localised eutrophication and pollution from waste food and faeces are often causes for concern when it comes to fish farms in shallow bays and estuaries, especially when it comes to sensitive habitats like the maerl beds located in Casteltown Bearhaven (Hession *et al.,* 1998). With aquaculture facilities, of both finfish and molluscs being found in Bantry Bay, Dunamanus Bay, Roaringwater Bay, Baltimore Harbour, and in the areas around Sherkin Island, this has the potential to become a major threat to the marine ecosystem. However, due to the EC's Water Framework Directive (WFD), this issue is becoming less prevalent However, this is not the sole environmental impact associated with aquaculture facilities in Ireland today. What is still of major concern for aquaculturists and conservationists alike is the issue of escapees from farmed fish cages. Escaped fish have been shown to have detrimental effects on native fish stocks, due to competition for resources, spread of disease, and alteration of genetic diversity due to hybridisation (McGinnity *et al*., 2003; Read and Fernandes, 2003). These issues are putting further pressures on an already declining wild fish stock in Irish waters. From a financial standpoint, these escaped individual represent a significant economic loss to the businesses involved. Damaged constructions, due to poor maintenance, bad weather and depredation, as well as the loss of stock, can result losses in the region of hundreds of thousands each year. In 2009 alone, the Irish aquaculture industry took a loss of almost €700,000 from the escape of 35,000 individuals (Jackson *et al.,* 2015). Losses like these, can hardly be described as

sustainable, and pose a serious threat, both to the marine environment, and to the coastal communities reliant upon this form of income.

One of the fastest growing aspects of mariculture is that of algae, or seaweed. Initially focused in Asia, this industry has been increasingly more prevalent in Western Europe, including Ireland. Currently 44% of all aquaculture is algal aquaculture (FAO, 2002). At present, algae is used in the food, cosmetics, pharmaceuticals, fertiliser and animal fodder industries, with 90% of all commercial algae sourced via aquaculture (Walsh and Watson, 2011). However, Ireland has a long history of harvesting algae for use in fertiliser, food and the production of pottery and glass as far back as the 12th Century (Guiry, 2010). Currently, the Irish algae industry has a value of €18 million per annum (Morrissey *et al.,* 2011), and is expected to reach €30 million per annum by 2020 according to the Sea Change Strategy (2006). Despite being under similar constraints as fish farming, the industry continues to boom. Annually, Ireland produces over 36,000 tonnes of algae (Walsh and Watson, 2011) through culturing facilities, such as the Roaringwater Bay Sea Vegetable Company. In spite of this hugely growing income, vast areas of West Cork have yet to utilise even the naturally present algae for commercial purposes. Advances in the techniques for the hatchery and ongrowing, particularly of kelp and dulce (*Palmaria palmata*), will lend to a further increase in this industry in Ireland, providing, not only additional income and employment, but also a whole range of new marine based products. Further advancements will also help alleviate the previously mentioned issues arising from aquaculture facilities.

One final issue facing the aquaculture industry is that of public backlash. Anecdotally, fish cages and mussel/algae lines have been described as “unsightly” and can affect the aesthetic beauty of an area, such as Roaringwater Bay. Complaints have also been made about unpleasant odours and water contamination arising from aquaculture practices, which can all have a detrimental effect on tourism and for the local community. Artisanal and recreational fishermen have also registered complaints with groups like “Save Bantry Bay”, about infringement on traditional fishing grounds (www2). Only through, clear and level headed discussion can a compromise be found that is beneficial to all parties involved.

2) Pollution

With the global population expanding with each generation, human beings have increased the pressures placed upon the marine environment. Industrial and agricultural advancements have also increased the level of waste products created, most of which end up in the world's oceans. Even inland communities are dumping unwanted, dangerous substances into the river systems which eventually connect with the coastal environment. Pollution has been a major aspect of conservation in both the terrestrial and the marine environment, with increased public concern and awareness especially in recent years. As far back as the early 1960's, campaigns began to emerge fighting for the protection of the seas from pollution. In 1972, the UN discussed marine pollution as a major global issue and this led to the signing of the London Convention. This convention did not outright ban marine pollutants, but instead created a black list of substances that could no longer be dumped into the oceans. Cyanide and radioactive waste are just two examples of these blacklisted substances (Darwin, 2008). In 2006 the convention was altered in a "reverse list" manner. Now all member states, including Ireland, rather than prohibiting dumping of specific materials, ban pollutants that do not feature on this new list. This new list includes sewage sludge, organic material in organic forms, industrial fish wastes, and inert geological materials (Krause *et al.*, 2006). Despite these measures, marine pollution is still a major problem, particularly for coastal areas, and are having knock-on effects for the communities reliant upon them. Some of the key issues effecting the coastal, marine systems at the moment are: emerging contaminants and toxins, marine litter, and the resuspension of sediments.

i) Emerging Contaminants and Toxins

Emerging contaminants are defined as diverse organic or inorganic compounds, usually found in very small amounts (nanograms to micrograms per litre) that can have deleterious effects on wildlife, humans and the ecosystem as a whole (Mostofa *et al.,* 2013a). Pharmaceutical production, pesticides and agricultural run-off, and sewage outflow are all considered as sources of emerging contaminants. Whether inland, or

coastal, the waste products of such facilities, make their way through the water system and into the marine environment, where their effects make themselves evident.

The influence of hormone medications, produced by many major pharmaceutical companies, has been noted in both freshwater and marine fish across Europe. According to Tyler and Jobling (2008), artificial oestrogen hormones, such as the contraceptive pill, are inducing feminisation in many fish species. With a majority female population, reproductive success of the species decreases, which puts additional pressures on stocks for the fisheries industry, as well as reduction in biological diversity. Antibiotics and other drugs can also be an issue in the marine environment, not only as causes of direct mortality for the organisms exposed to the contaminants, but for anything that feeds on these creatures, such as humans. These compounds tend to bio-accumulate, meaning the substance cannot be removed from the body and so concentration continues to increase with exposure. Dangerous chemicals can build up in the flesh of fish and then be digested by human beings, causing serious, and even life threatening, illnesses (Halling-Sorensen *et al.,* 1998). Rather than the companies, themselves, directly dumping (although this has been reported) the major cause for pharmaceutical products entering the water system is through incorrect drug disposal by the general public (Jones *et al.,* 2001; Islam *et al.,* 2010). Expired or excess tablets and medications, are often poured down sinks, or flushed for “safety”, but in fact are causing more harm than good. Only with correct drug disposal can this issue be resolved.

A second major pollutant in the coastal environment is agricultural run-off. Rainfall can cause any chemicals or fertilisers applied to crops or livestock to be washed off into river systems and be carried downstream to the sea. In recent years the use of toxic biocides, like DDT, have been reduced, but fertiliser is still causing major issues. Nitrates and phosphates in the fertilisers are major causes of nutrient enrichment, also known as eutrophication. This increase in nutrients can directly cause algal blooms, which can pose dangers to marine life and humans alike. In recent years, these blooms have become increasingly more frequent (Sellner *et al*., 2003). What makes the blooms so detrimental to the marine environment, is the resulting oxygen depletion. The nutrients in the water cause the rapid growth of algae, which continue to proliferate until all nutrient supply has been exhausted, the algae then dies off and sinks to the

seabed where bacteria help break it down. It is this breakdown that reduces the level of oxygen in the water, creating anoxic “dead zones” where it is impossible for most marine organisms to continue their survival. They are of particular danger to sessile, benthic organisms, such as anemones and corals, which do not have the ability to move to an area with higher oxygen levels. Also known as red tides, these blooms occur almost annually around the Irish coast, even in areas free from industrial influence like Lough Hyne Marine Reserve (Jessopp *et al*., 2007). Many of these red tides also contain harmful toxins that can become airborne, causing health complications in humans and animals alike (Watkins *et al*., 2008). These toxins can also bio-accumulate in filter feeding organisms, like mussels, which is what causes neurotoxic shellfish poisoning, a disease caused by the consumption of contaminated shellfish. In 1997, up to two dozen people contracted diahrretic shellfish poisoning from consuming only 10-12 individual mussels (Twiner *et al*., 2008). Depending on toxicity levels, species and site, the incidence of these infections can range from 0.2% to 14% (Hinder *et al*., 2011). This poses particular danger to the shellfish industries based out of Bantry Bay.

Another contaminant contributing to algal blooms is untreated sewage entering the marine environment. This waste also brings with a hold host of harmful bacteria that, again, can be severely detrimental to human and environmental health. Bugs like *Escherichia coli* can enter the water column and be taken up by commercially farmed (and wild) shellfish. For example, in 2015, over 50% of all mussels tested in Bantry Bay and Dunamanus Bay exhibited unsafe levels of *E.coli* in their tissues, and so were deemed unfit for human consumption (EPA, 2015). Recently though, nitrate levels have decreased by almost 19% and phosphate levels by close to 38%, which is a good sign for Irish coastal waters. Due to the WFD and work carried out by the Department for the Environment, sewage treatment and disposal have come on greatly. It is for this reason that in the latest EPA water quality report (2015) shows that 67.4% of Irish coastal waters are in “moderate to good” quality, in terms of ecological health. There are still areas in danger from marine pollutants, such as the Argideen estuary, which still is classified as “poor quality” due to opportunistic macroalgae.

ii) Marine Litter

Marine litter, or debris, is fundamentally linked to human activity. Through industrial activity and incorrect waste disposal, tonnes of debris enters the marine environment every single day, equating to roughly 10 million tonnes each year. Litter enters the marine environment directly from discarding on vessels, or through terrestrial sources, either through river or drainage systems (Derraik, 2002). It has become a globally recognised problem, with Irish people considering it a more serious issue than that of terrorism, second only to pollution as a whole (Hynes *et al*., 2014). This litter, not only creates unappealing aesthetics for a coastal area, but also causes many serious complications for marine life.

A wide range of marine animals, including seabirds, invertebrates, turtles, fish, and marine mammals, can easily become entangled resulting in serious, and often fatal, injury (Kuhn *et al.*, 2015). Entanglement, poses a particular threat to marine mammals, like seals and dolphins. In Irish waters, over half of all seal deaths between 1994 and 1999 were as a result of accidental entanglement, be it in active fishing nets or discarded debris (Rogan *et al*., 2001). Additionally, litter can be eaten by many sea creatures, causing digestive problems and eventual death. For example, 13 sperm whales found stranded in the North Sea area in 2015, were found to have eaten fishing nets, car parts, and even a plastic bucket, before stranding along the German coastline. Sea birds, are the most commonly threatened group by ingestion marine littler. Current studies show that over 70% of all seabirds have some form of marine litter in their stomachs, with plastics being the major contributor (Wilcox *et al*., 2015). On the seafloor, many benthic organisms can die from anoxia (lack of oxygen) as a result of marine debris smothering the substratum (Moore, 2008). This would pose serious dangers to areas like seagrass beds, found commonly around the Irish coast *e.g.* Barley Cove, Lough Hyne.

The major contributor to marine litter, is plastics. It has been shown that 10% of all plastic produced end up in the marine environment (Thompson, 2006). Not only do plastics pose all the same dangers to aquatic life as previously mentioned, it is also extremely slow to breakdown and so persists in the oceans years after it entered the water. If global plastic production was to halt now, the plastic in the world’s oceans

would not disappear completely for at least 1,000 years (van Sebille *et al*., 2012). Floating plastics tend to aggregate within circulating ocean currents, also known as gyres, with the largest being found in the Pacific Ocean (Kaiser, 2010). This “garbage patch” is the largest of the 6 located in the oceans around in the world, including the Atlantic. It is thought that there is more plastic located in these patches than there is marine life (van Sebille *et al.*, 2012), with the majority of the plastics, being broken down particles of larger pieces, known as microplastics. With UV radiation breaking down plastics to these microscopic sizes, many of the toxic materials used to create plastic are entering the marine food chain (Teuten *et al.,* 2009). The larger surface area of these particles also causes the aggregation of emerging contaminants, which can also enter the food chain (Lusher *et al.*, 2015). This can have knock on effects to the physical health of people in coastal areas, and inland.

From an Irish perspective, marine litter is a major issue. 57% of all coastal waters have been found to have varying degrees of marine litter, with almost half of this litter being made up of plastics (Moriarty *et al.,* 2016). This litter is causing huge problems for marine life but also the beauty of the country that draws so many tourists to our shores. Initiatives like Tidy Towns and An Taisce’s Clean Coasts, are helping to combat these problems. In 2014 alone, beach clean ups run by Clean Coasts noted thousands of individual pieces of litter on our nation’s beaches: over 5,000 plastic bottles, 4,000 aluminium cans, over 2,000 pieces of rope and netting (www2). Work like this does seem to be improving the situation in West Cork though. In 2015, 5 beaches were awarded Blue Flags, as a symbol of high quality bathing waters and beach cleanliness. These beaches are: Ring, Barleycove, Tragumna, Owenahincha, and Inchydoney, the last of which was also awarded Cork’s only Green Coast Award.

iii) Resuspension of Sediments

Coastal marine sediments, particularly those in estuarine environments, are home to wide range of benthic organisms from small invertebrates, marine plants, and flatfish species. This type of seafloor is in a delicate balance and can be easily disturbed by human activity such as shipping traffic, bottom trawling and dredging. Once disturbed, fine sediments can become resuspended in the water column creating many problems

for marine life. These problems include: chemical disturbance, eutrophication, alteration of sediment structure, burial and smothering, and increased turbidity (OSPAR, 2011). Chemical disturbance refers to the remobilisation of toxic materials, such as heavy metals (*e.g.* Lead (Pb) and mercury (Hg)). One example of this can be seen in Bantry Bay, where heavy levels of shipping traffic have caused a resuspension of Tributyl tin (TBT) (Hoch, 2001). TBT poses a particular risk to molluscan species like the dogwhelk (*Nucella lapillus*). This whelk, takes in TBT with its prey, where a build-up of the toxin leads to reproductive abnormalities preventing successful production of larvae (Murphy *et al.,* unpublished). Increase in turbidity (cloudiness of water) can limit the amount of light that can penetrate the water column, posing a threat to light dependent organisms like marine plants and photosynthetic phytoplankton. Without light these organisms eventually die, initially removing a food source for any herbivorous creatures, but the breakdown of these dead organisms leads to eutrophication and hypoxic dead zones. Large levels of sedimentation, caused predominantly by dredging or dumping, can also crush and smother many of the delicate marine flora and fauna.

In Irish waters sedimentation is still an issue in 2016. Between the year 2009 and 2013 almost 3 million tonnes of sediments were dumped into the sea, with up to 56 tonnes of this being comprised of purely toxic metals (OSPAR, 2013). The majority of this sedimentation occurs in the Shannon estuary and off the South East coastline. However, with proposed harbour developments planned to go ahead in Schull, this could begin to be a major issue for South West Cork. Although harbour expansion related sedimentation is usually a temporary, localised issue, it could still have profound long term effects for the brittle star (*Ophiurida spp.*) and banded venus (*Clausinella fasciata*) which live in the muddy sand around the current marina (MERC Contractors, 2007). Shipping traffic in busy fishing areas, such as Union Hall and Bantry Bay, pose a more long term issue, as the sediment disturbance is continuous and can only be halted with the halting of shipping traffic, which in turn would cause countless issues for any businesses relying on this traffic.

3) Climate Change

As previously stated, coastal areas and the marine ecosystem have already been placed under a wide range of direct anthropogenic pressures, but there are indirect pressures stemming from human activity that are having a more serious effect on the global climate. Global warming now known as climate change is a key topic of discussion around the world, with most people having at least a general understanding of what is occurring today. What is not as generally realised is that climate change, although it does occur naturally, has been aggravated and expedited by the influence of humans. Increased CO_2 emissions in the last 100 years are having profound effects on atmospheric and sea surface temperature, and sea levels around the world. These changes are having further knock on effects on weather patterns and ocean currents, which further increase levels of coastal erosion and ocean acidification. Another major issue arising from changing climates is the number of non-native or invasive species being discovered outside of their usual habitats, which can pose major threats to native flora and fauna. Although the concept of climate change in coastal environments seems relatively simple, it is far more complex when looked at from a wider perspective.

i) Temperature and Sea Level Change

On a global level, there has been a general increase in average temperature of 0.1°C since 1961 (Nolan *et al.*, 2009). Highest rates in Ireland were observed between 1993 and 2003 with an average increase of 0.6°C. Known to be a result of heightened levels of greenhouse gases, atmospheric temperature increase is having detrimental effects on the entire planet. A study by Cannaby and Hüsrevoglu, (2009) has listed many of the resulting effects of “global warming” including rising sea temperatures and altered salinities. Increased temperatures have caused serious decreases in the thickness of the polar ice caps which, not only is devastating for the plants and animals found in polar regions but, has created a higher influx if freshwater, particularly in subpolar regions. Although no specific trend has been observed in Irish waters, in terms of reduced salinity (Nolan *et al.*, 2009), there has been a noted increase in salinity within the North Atlantic Subpolar Gyre since 1995. Increased temperature has also been observed within this cold current which interacts with the warmer Gulf Stream to create

the weather patterns observed along much of the west coast of Ireland. Increased rainfall associated with the warming of these two currents combined with rising sea levels is contributing to the annual retreat of 0.5-1m of Atlantic coastlines (Cooper and Pilkey, 2004). Melting ice caps are not only adding more freshwater to the oceans, but causing them to rise. Sea level are rising at roughly 2mm each year, with European waters exhibiting 50% higher rates than other areas (Woodworth *et al.,* 2005). By 2100, sea levels are estimated to be up to 1.2m higher than they are currently. For coastal areas this causes serious concern. Residential property, agricultural lands and, local businesses could all be under water in less than 100 years, representing billions in lost income for the people of South West Cork. Not only that but, beaches and wetlands are being constantly altered and destroyed by rapidly changing weather patterns.

ii) Weather and Coastal Erosion

Shifting weather patterns along the Irish coastline have been adding to the coastal retreat, linked with rising sea levels, through coastal erosion. Although storm frequency has decreased in the last few decades, the intensity of winter storms has been rapidly increasing (Sweeney *et al.,* 2003; Dunne *et al.,* 2008). These storms not only erode the coastline, but cost millions in structural damage, flooding, and loss of fishing vessels and equipment, to name but a few. Erosion of the Irish coastline, particularly the South West, is further aggravated by positive trends in the North Atlantic Oscillation which has led to an increase in wave height of 0.8m every ten years (Woolf *et al*., 2002). Of the 7,800km coastline 1,500km are deemed to be “at risk” from coastal erosion, with a further 490km being in “immediate danger” (DELG, 2001). Areas such as Bantry Bay and Dunamanus Bay have been noted to be areas of particular concern (Devoy, 2008). Current estimates state that the rate of erosion for the Irish coast is between 0.2m and 1.6m per annum (DELG, 2001), with sand dunes and soft cliffs being the worst affected. Soil type, as well as storm intensity and wave height, play a huge part in the level of erosion, as does the presence of lose rock and stone within the water (Summerfield, 1999). Through attrition and wave action, sandy areas like Castlefreke or Long Strand can lose up to 10m of dune in a single storm event. However, sandy areas are usually only damaged in the short-term, as accretion can allow for soft sediments to be replenished; rocky, hard soil areas are where the

long term effects of coastal erosion can be seen more obviously (Thom and Hall, 1991).

With the realisation of the threat coastal erosion is posing to the Irish people and the economy, several preventative measures have been put into place. These measures can be divided into two categories: hard and soft. An example of a hard measure is the construction of sea walls and/or groins, such as those found in Rosscarbery. Sea walls act as a physically resistant barrier to wave and storm action, and can greatly reduce the threat to coastal areas. Currently, no less than 350km of Irish coastline are protected by artificial sea walls (Devoy, 2003). The draw backs of sea walls, is that they are expensive to build and are usually only put in places where the cost of construction is less than that of any potential property damage or losses. Sea walls can also cause more long-term issues, such as the reduction of accretion in other coastal areas by depriving them of sediments that would previously have been products of erosion. Soft measures include methods like “beach replenishment”, where sand and sediments are transported from off shore and added to beaches post-erosion events. Although highly uncommon in Ireland, it has had increasing emphasis placed upon it as a way of restoring lost beaches (RIKZ *et al*., 2004). The Irish government have invested €44million to address the growing issue of coastal erosion as part of the National Development Plan 2000-2006. With this funding, erosion can be dealt with in a manner that is beneficial to humans as well as the environment.

iii) Ocean Acidification

The world’s oceans absorb almost half of all carbon emissions, and can hold up to 50 times more CO_2 than the atmosphere (Sabine *et al.,* 2004). Increasing greenhouse gases have caused the oceans to become saturated in CO_2, and so are losing the capability to act as carbon sinks. It is also driving the ocean pH towards being more acidic, while also reducing levels of carbonate ions (CO_3^{2-}). By 2100, marine CO_2 levels could reach 880ppm (parts per million), which would imply unprecedented impacts on the marine environment (EC, 2013). This would cause a drop in pH from the current 8.2 to 7.9, increasing ocean acidity by 150% since preindustrial times (Raven *et al.*, 2005; McNeil and Matear, 2006; Feely *et al*., 2009). This increased acidity is thought to be to blame for major coral bleaching events observed in the Great

Barrier Reef, where losses of 25% are expected within the next 40 years if current trends continue (Wild *et al*., 2011). Cold water corals, found off the Irish coast are also in danger from these pH alterations. Lower levels of carbonate ions create immediate dangers for many marine organisms, such as zooplankton, molluscs, and corals, and indirect threats to fish, seabirds, marine mammals, and humans. The immediate danger stems from the need for carbonate ions in the formation of shells like those of mussels and marine snails. Without appropriate levels these organisms become easily damaged and mortality rates increase. Not only does this reduce the biodiversity of the coastal environment, but shell and finfish aquaculture industries can be hit with serious economic losses. The fisheries industry can also suffer, as a major food source for many of their stocks could suddenly decrease, resulting in lower populations and lower quality individuals for commercial sale.

iv) Invasive Species

Climate change has also indirectly influenced the presence of non-native, invasive species in Irish coastal waters. Of the 377 currently known invasive species in Ireland, 12% are marine based (O'Flynn *et al*., 2014), many of which place further pressures on the environment and the communities that rely upon it. Rising sea temperatures allow organisms to survive in areas where it would previously have been impossible. For the most part, many invasive species are relatively harmless, the danger appears when they begin to displace native species. This displacement can be caused by competition for resources, hybridisation, predation, and the alteration of food webs and community structures. Economically they can be damaging through diminishing of fisheries, biofouling of hulls and aquaculture equipment, clogging of outflow pipes, and the spread of disease (Ruiz *et al.,* 1997). Even a small number of invasive species can have dramatic effects, and once established can be almost impossible to remove (Mack *et al.,* 2000; Thresher and Kuris, 2004). Currently the best method is prevention rather than eradication. While the survival of many invasives is linked to climate change, increases in transport and aquaculture have created new pathways and vectors for these species to enter Irish waters. Ireland, as an island nation, is at particular risk to invasives. The ecosystem here is in a more delicate balance, with a reduced number of native species compared to mainland Europe (Drake and Mooney, 1989; Stokes *et al.,* 2006). In 2002 a National Biodiversity Action Plan was put into

place by the Department of Arts, Heritage, and the Gaeltacht, with particular focus on invasive species. Three of the major invasive species identified as threatening to the coastal marine environment are: Japanese wireweed (*Sargassum muticum*), the freshwater zebra mussel (*Dreisenna polymorpha*) and escapee Atlantic salmon (*Salmo salar*) imported for aquaculture. Bonamiosis, a foreign parasitic disease, has also been observed in native flat oysters (*Ostrea edulis*).

Wireweed originated in Japan and was first observed in Strangford Lough, Co. Antrim in 1995. This fast growing marine plant is thought to have been introduced with the import of Japanese oysters before becoming widespread across Ireland (Thomas, 2002). Its main threats consists of biofouling and out competing other marine algae for light and nutrients. Zebra mussels were first introduced via ballast water in the Shannon estuary in the 1990s, and have colonised many estuarine and river systems (wwwIFI). Originating the Black and Caspian seas, these mussels are known to be competing with other sessile organisms for food and space, as well as the clogging of outflow pipes and biofouling of lines. Although they have yet to be reported in Co. Cork, careful monitoring is needed to prevent the spread. Imported salmon, although the species itself is native, can cause major genetic disruptions through hybridisation if released into wild populations, as well as competing with native fish for space and food. Large scale escape incidents, due to bad weather and damage to fish cages can be especially detrimental. In February of 2014 between 60,000 and 80,000 imported salmon escaped from an aquaculture facility in Gerahies due to severe storm damage, creating a serious threat to the wild salmon of the Bantry area. However, it is not just the individual species that are creating additional pressures on the coastal environments. Microscopic organisms, like *Bonamia ostrea*, can cause serious invasive diseases in native species. First introduced to Ireland in 1987 through imported Pacific oysters (*Crassostrea gigas*), this disease spread rapidly in Rossmore native oysters (McArdle *et al.,* 1991). The disease itself attacks the tissues of the oysters and has caused up to 90% mortality in some cases (Culloty and Mulcahy*,* 2007). Originally thought only to effect mature individuals, more recent studies have shown that even oyster larvae are susceptible to infection (Lynch *et al.,* 2005). Only with time, funding, and rigorous controls can the threat posed by invasive species be reduced, and the coastal environment protected.

These are just some of the known detrimental effect that changing climates are having on the planet today. It is quite possible that with continued research and investigation, an entirely new side of this phenomenon will be revealed. What is known, and has been proven, is that the human race is responsible for the vast majority of these rapid changes. Added pressures of temperature changes, shifting weather patterns, changes to oceanic chemistry, and introduction of non-native species to new areas, are creating even more difficulties for the marine environment. Earth's ecosystems cannot withstand these pressures indefinitely. Eventually something has got to give. Something as simple as reducing carbon emissions, could have untold benefits in terms of slowing these changes to the planet's environment. Although most of these problems cannot be eliminated immediately, they can be reduced in scale, giving the marine environment, with all its biodiversity, time to recover to a sustainable level.

4) Biodiversity and Conservation

The diversity of marine life is key to the functioning of the coastal environment. A rich level of biodiversity has positive influence on the services the seas provide to humans, such as food, tourism, and general health (Duffy, 2003). It is therefore, important to understand how the differing levels of the ecosystem contribute to the whole. With this understanding it is possible to identify areas that require particular attention and protection. Through scientific research, areas of concern can be highlighted and proper measures taken to ensure the continued success of the ecosystem, through proper funding and enforcement of environmental policy and legislation.

i) Food Webs and Ecosystem Levels

The concept of food chains and webs is widely discussed, but can be frequently poorly understood. Complex interactions between marine organisms and their environment are what produce the resources utilised by coastal communities around Ireland, and the rest of the world. The basis of any food web, including the marine, is that of a primary producer. These organisms are the lowest level of the chain and provide all other levels with the energy required for survival. Photosynthesising phytoplankton

(*e.g.* Diatoms, Coccolithophores, Dinoflagellates, and Cyanobacteria) utilise the sun's energy to grow and reproduce and act as a vital food source for the next level of the web. Other primary producers include larger algae and marine plant life. The next level is made up of the smallest floating animals: zooplankton. These organisms can be single celled or multicellular, such as amoeboids and cillates, and are eaten by larger zooplankton, like copepods and larval forms of mussels and jellyfish, small fish, and marine invertebrates. Larger fish (*e.g.* herring [*Clupea harengus*]), jellyfish, squid, krill, and larger plankton feeders like baleen whales make up the third level of the web, which in turn are fed upon by the top predators. These top predators include, seabirds, marine mammals, and large predatory fish (*e.g.* Albacore tuna [*Thunnus alalunga*]). Finally, come human beings. Humans, as previously discussed, are what are posing the biggest threat to marine biodiversity. As human activity in coastal areas has increased, globally there have been dramatic reductions in marine biodiversity (Duffy, 2003). Reducing the populations of lower level organisms have knock on reductions to the higher levels, through depravation of food sources. Conversely, reducing the number of predators will cause an increase in numbers of the lower levels which will result in a "boom" of production in the lower levels. On a long term basis, this rapid proliferation eventually creates a depletion of resources leading to competition and population decline of the lower levels until the web itself collapses and ceases to exist.

Bottom trawling and dredging pose a most serious threat to the marine environment. Resuspended particulate matter prevents photosynthesis from occurring by blocking light. Without primary production the food web cannot continue to function. Even detritivores cannot survive once other organisms are removed. This delicate balance is further tipped by several traits of the creatures within the web. Small population size, small geographic range, slow growth and reproduction rates, and specialised ecological habitats are all natural limiting factors, which are placed under further strain by human activity (Pimm *et al.,* 1988; Lawton, 1995; Didham *et al.,* 1998; Purvis *et al.,* 2000). It is for these reasons that certain areas and species come under legislative protection through the establishments of Special Protected Areas (SPAs), Special Areas of Conservation (SACs), and Marine Protected Areas (MPAs) and Reserves.

ii) Protected Areas

In a biological conservation context, protected areas can be divided into 3 categories: Special Protected Areas, Special Areas of Conservation, and Marine Protected Areas. Although the names appear similar there are certain differences that set these categories apart. These differences consist mainly of what is protected in each category and what legislative body has defined them as such.

1-Special Protected Areas (SPAs)

SPAs apply to the birdlife of Ireland. Mainly based around marine islands and cliffs, these areas provide nesting sites for the 500,000+ individual seabirds from 24 species. Almost 600,000 hectares of Ireland have been designated as SPAs by the NPWS under the Birds Directive (EC, 2009). The coastal areas include productive intertidal zones of bays and estuaries that provide vital food resources for several wintering wader species including Dunlin (*Calidris alpina*) and Bar-tailed Godwit (*Limosa lapponica*). Marine waters close to the breeding colonies and other important areas for sea ducks, divers and grebes are also included with SPAs. The majority of the wintering and breeding seabirds and are considered to be regularly occurring migrants. Over 60% of 25 Annex I species that are found in Ireland regularly belong to these two groups. This has been a major factor of the situation that more than 80% of Ireland's SPAs are designated for these two bird groups. Of the 154 SPAs around Ireland, three coastal areas of South-West Cork have been designated as Special Protected Areas: Clonakilty Bay, Gallyhead to Duneen Point, and Sheep's Head to Toe Head.

2-Specaial Areas of Conservation (SACs)

SACs cover the protection of several species within the area and are defined by the NPWS under the EU Habitats Directive (EC, 1997). These areas are defined as "important on a European as well as Irish level" by NPWS. Each SAC has a specific management plan identifying features of conservation interest. These features include

both marine life and geographical structures. Within South-West Cork, 12 different SACs have been defined as of April 2016 (www1NPWS):

- Clonakilty Bay
- Myross Woods
- Roaringwater Bay
- Barleycove to Ballyrisode Pt.
- Dunbeacon Shingle
- Farranamanagh Lough
- Glengariff Harbour and Woods
- Kilkeran Lake and Castlefreke Dunes
- Castletownshend
- Three Castle Head to Mizen Head
- Reen Pt. Shingle
- Sheep's Head

Taking Roaringwater Bay as an example, there are three Annex II species protected here: the grey seal (*Halichoerus grypus*), the harbour porpoise (*Phocoena phocoena*), and the otter (*Lutra lutra*). Seabird species such as Fulmars, Shags and Guillemots are also under legislative protection in these areas, as well as smaller organisms like feather stars (*Antedon bifila*), bivalve species, and polychaete worms. The geographical features of interest in Roaringwater Bay have been listed as: large, shallow, inlets and bays, subtidal reefs, vegetated sea cliffs, dry heaths, and sea caves.

3) Marine Protected Areas (MPAs)/ Marine Reserves

Like the name suggests, these areas are specifically marine and function exactly like SACs. Currently, Ireland's only statutory marine reserve is found at Lough Hyne. Established in 1981 (www2NPWS), this highly biodiverse sea lough can be found roughly 6km south of Skibbereen. It is unusual in that it has a relatively high number of species for such a small area (DAHG, 2013), at just over 400ha. Lough Hyne's rare sheltered reefs provide a home for many species rarely found in Ireland if at all. The declining purple urchin (*Paracentrotus lividus*), the soft coral (*Paraerythropodium coralloides*), and two rare species of goby: Couche's goby (*Gobius couchi*) and the red-mouthed goby (*G. cruenatatus*) all call Lough Hyne their home (DAHG, 2013). In all of Ireland, southern cup coral (*Caryophillia inornatus*) is only found in Lough Hyne. These are just a few examples of the variety of organisms found in the marine reserve. The lough was assigned protective status after over 100 years of scientific research

carried out at the site (Kearney, 2013). It is through scientific research and investigation like this, that conservation and protective legislation can be properly informed and implemented.

iii) Scientific Research

Through rigorous scientific investigation and research, the pressures and changes to the coastal marine environment are possible to identify and conservation efforts engaged. Most research involving conservation and biodiversity in Ireland is carried out by public and private institutions working with and for government bodies. Organisations like the Environmental Protection Agency (EPA), the Irish Marine Institute, and the National Parks and Wildlife Service, as well as universities, are all key players in the understanding of what is occurring in the marine environment today and how trends have changed over time. A recent study has shown that the general public believe that scientists are the best suited group to manage the marine environment, with over twice that of local and national governments (Hynes *et al.,* 2014). What the public may not realise is that they too can play a key role in scientific research.

Increasingly, scientists have realised how valuable non-scientists are as a resource, both in terms of data collection and information processing. “Citizen science” has been identified to be highly useful, particularly in the ecological field. Projects revolving around topics such as climate change, invasive species, conservation biology, ecological restoration, water quality, population ecology, and a variety of monitoring aspects, have all gleaned valuable information from the involvement of citizen scientists (Silvertown, 2009). Especially when field work is required, members of the public can provide a low cost, often free, method of collecting large amounts of data very quickly. Advancements in technology such as good quality smartphone cameras are continuing to help involve members of the public in scientific research (Dickinson *et al.,* 2012). Through the Freedom of Information Act and the Aarhus Convention (UNEC, 1998), members of the public are not only encouraged to be involved in environmental management, but actually have the right to access information and voice their opinions. However, in Ireland, this appears to not be generally known, and so is less frequently occurring. It is through creating a dialogue between trained

scientists and citizen scientists, that the most effective methods of environmental monitoring and management can be put in place.

iv) Ecotourism

It is not just those resident in coastal areas and scientists that are utilising the marine environment in Ireland. Tourism has always been associated with sun, sea, and sand, and (despite Ireland occasionally lacking in that first one) this continues to be the case today. 63% of all tourists make use of the coastal regions (Davenport and Davenport, 2006), and with decreasing costs of airfare and travel, this figure is expected to rise. By 2020, it is estimated that over 350 million tourists will annually utilise the coasts of the Mediterranean alone (WTO, 2004). With increased desires of tourists to explore the natural world while holidaying, the ecotourism industry has been growing rapidly in recent years. Hillwalking, SCUBA, kayaking, and whale watching are just some examples of how the coastal marine environment has been utilised as a valuable form of tourism driven economics. Although deemed as low environmental impact activities, there have been noted detrimental effects on the ecosystem as both direct and indirect results of the ecotourism industry.

The greatest of these threats comes from the expansion of infrastructure, such as the construction of hotels, improvement of roadways, and increased footfall and traffic (Davenport and Davenport, 2006). Habitat destruction, pollution, litter, and direct disturbance of wildlife, are all widely occurring during infrastructure expansion. Personal watercraft and poorly trained SCUBA divers have also had noted effects on the marine environment through disturbing of marine animals, damage to corals and algae, and the resuspension of sediments (Cubero-Pardo and Bastidas, 2008). Anchor damage and ballast discharge have also been mentioned as two leading causes of decline in coastal marine biodiversity, both in Ireland and the world in general (Lewis, 1985). Beach walkers can accidentally trample plant life, which plays a major role in the maintenance of sand dune structure and stability. Uninformed whale watching tour operators can unintentionally traumatise and frighten whale and dolphin species by being in too close a proximity to the animals. Kayakers can potentially damage marine life attached to piers, jetties and, slipways. There is potential pressure brought in with

each activity that can only be reduced through ecological awareness and correct practice.

For the most part though, Irish ecotourism operators, particularly in South West Cork, are in good practice and well informed on environmental issues and how to best reduce the impacts while still maintaining a viable business. Most SCUBA training agencies incorporate the importance of correct technique and control to avoid damage and disturbance to marine life. Sand dune walkways, such as those found at Barleycove, help keep walkers away from sensitive areas, therefore preserving the natural dune structure. Whale watchers are well informed and educated enforcing strict time and distance restrictions, many of which vary by the species in question. It is for reasons like these that the threat posed by ecotourism in Ireland is being minimised, allowing it to continue to draw thousands of tourists to the coast each year.

v) Awareness and Costs

Public awareness of the importance of marine conservation is growing. Through research, ecotourism, and the media, more and more people are starting to understand the importance of services provided by the coastal marine environment. Irish people have identified the marine environment as most important for its scenery, recreation and tourism, a source of food, employment, and, to a lesser extent, part of national culture and identity (Hynes *et al.,* 2014). With this growing awareness comes the pressures upon the Irish government and industries to instate more eco-friendly policies and measures. For example, in 2016 the Irish government allocated €2 million towards climate change research and mitigation as part of the International Green Climate Fund. With these new policies and initiatives, though, come costs; both public and private research contractors all require funding, rangers and other staff members need to be paid, and the erection of protective structures does not come cheaply. Limited funds creates a particular difficulty in the enforcement of environmental policy. For example, the NPWS is the main enforcer of the protected status of SPAs, SACs and MPAs, but, due to lack of proper funding, only a single ranger has been employed to oversee South West Cork and South West Kerry (DAHG, 2013). Insufficient manpower as a result of poorly allocated funds makes it next to impossible to ensure

the conservation of the coastal marine environment. Only through higher levels of funding and public involvement can these conservation methods be implemented fully.

Once the complexities of food web structure, through the important of scientific research being carried out by professionals and the pubic, are more generally understood the key role biodiversity plays in the maintenance of the coastal marine environment will become of greater public concern than it already is. Through proper protective measures, with correct and appropriate levels of funding, the coastal marine environment will continue to provide all of the valuable services, not only to coastal areas, but to the whole of Ireland.

5) Policy and Legislation

With mounting anthropogenic and ecological pressures on the coastal marine environment, global governments are realising the importance of the services provided to coastal communities by the marine ecosystem. On both a national and international level, several vital pieces of legislation and policy guidelines have been put into force over the last number of years. European initiatives like the Oslo Paris Convention (OSPAR) and the Common Fisheries Policy (CFP), are further supported by the Birds and Habitats Directives, along with the Water Frameworks and Marine Strategy Frameworks Directives (WFD and MSFD respectively), the Nitrates Directive, adding further levels of protection to the marine environment on an international level. The Irish government has also decided that further knowledge and conservation is needed, and so have come up with a National Biodiversity Plan. All of the above policies and legislations cannot be effectively enforced by the EU and national governments alone, which is where the National Parks and Wildlife Service play a most crucial role. Here each of the above policies and bodies will be briefly summarised.

i) The OSPAR Convention

The initial Oslo and Paris Conventions covered European Union waters and stemmed from the Bonn Agreement in 1969, which came into place to grant protection to the

marine environment from oil-based pollution. In 1974, the Oslo Agreement was brought into place to give protection from dumping at sea by aircraft and ships, followed by the Paris Agreement in 1978, preventing the pollution of the marine environment from land-based sources (wwwOSPAR). On the 22nd of September, 1992, at the Ministerial Meeting of the Oslo and Paris Commissions, what is currently known as the OSPAR Convention was opened for signatories. This new convention for protection of the marine environment was signed by the EU as well as 15 individual countries: Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, the Netherlands, Norway, Portugal, Spain, Sweden, UK, Luxembourg, and Switzerland. This new convention included all previous decisions, amendments and recommendations of the previous three agreements, but added new conditions divided into five annexes. These annexes are as follows:

- Annex I: Prevention and Elimination of pollution from land-based sources
- Annex II: Prevention and Elimination of pollution by dumping and incineration
- Annex III: Prevention and Elimination of pollution from offshore sources
- Annex IV: Mandatory Assessments by each signatory state of the quality of the marine environment
- Annex V: The protection and conservation of the ecosystems and biological diversity of the maritime area.

The OSPAR Convention came into force from the 25th of March, 1998, strengthening and driving improvements to several pre-existing conservation driven directives and policies, such as that of the CFP.

ii) The Common Fisheries Policy

The Common Fisheries Policy (CFP) deals with the management of European fishing fleets, the conservation of fish stocks, and implementing aquaculture control measures. Member states of the EU have access to all European waters to generate fair competition under this policy first introduced in the 1970s. Updated in 2014, the CFP introduced several new limitations, such as the discard ban, and is comprised of four separate but interlinking components. The first component deals with the

regulation of production quality, grading, packaging, and labelling of seafood products. The second encourages producer organisation in order to protect fishermen from sudden market changes. The third component sets minimum prices for seafood products and finances the buying up of unused fish. Finally, the fourth component sets trade rules between non-EU and Member States.

Other aspects of the CFP include, but are not limited to: implementation of quotas and Total Allowable Catches, fishing controls such as closures and minimum landing sizes, funding for the upgrading of vessels, gear, and processing methods. The CFP also provides control and management frameworks to recreational fishers, and to the sustainability and low environmental impact of commercial fisheries and aquaculture facilities. These are just a few examples of what the CFP entails, the entirety of which is laid out in EU Regulation No. 1380/2013 (2013).

iii) The Birds Directive

One of the oldest pieces of environmental legislation, the Birds Directive was first adopted by the EU in 1979, and was later amended in 2009. This directive grants protection to the native and migratory birds of Europe, providing a relief of pressures stemming from habitat degradation or reduction as a result of forestry, agriculture, fisheries, and the use of pesticides. It is this piece of legislation that led to the establishment of SPAs, and gives restriction to the use of poison baits, capture, and hunting of the 500 bird species within the EU. Adapted each time a new Member State joins the EU, five annexes have been laid out to protect and conserve bird species and their habitats.

Annex I represents 194 individual species and subspecies, and specifically deals with the allocation of SPAs. Annex II deals with hunting procedures for 82 species, stating the timing at which hunting of certain species is permitted. This includes a total ban on all forms of hunting during migration to nesting sites, and at times of reproduction and chick rearing. Annex III covers 26 species and the deliberate threats posed to these birds by humans. Only with the tightest restrictions are the killing, capture, trade, and disturbing of nests of these birds permitted. The fourth annex bans all forms of mass killings of bird species, and lays out sustainable hunting practices for Member States.

The fifth, and final annex promotes research to exemplify the protection, management and use of all species contained within the Directive. The establishment of the Birds Directive directly led to the formation of the Habitats Directive.

iv) The Habitats Directive

This Directive was adopted by the EU in 1992, and is based around the protection and conservation of all habitats, flora and fauna of Member States. It aims to maintain biodiversity while taking account of all social, economic, cultural, and regional aspects of each country. Working in conjunction with the Birds Directive, a further five annexes have been laid out separately within this piece of legislation, the first of which demands the definition of each individual habitat type and the features of interest within them. Annex III enforces both site and species specific assessments, while defining the importance of the habitat to the local community. Annexes II, IV, and V all govern species protection. II covers roughly 900 species of plant and animal, specifying that sites must be managed with the ecological need of each species as paramount. IV enforces a strict protection regime across the entire range of a species, both within and outside of designated areas. Annex 5 ensures that any exploitation or taking of species is compatible with favourable conservation status.

Another factor of the Habitats Directive includes the implementation of Species Action Plans to restore and maintain populations of particular species. Furthermore, all Member States must provide regular reports on the status of their habitats and species, and on any compensatory measures put in place by the State. The Directive is constantly improved and amended based on the advice of a specialised Habitats Committee. However, from a marine perspective, habitat conservation and protection can only be effectively carried out by ensuring clean and suitable water quality. This was the reason for the establishment of the Water Frameworks Directive and the Marine Strategy Frameworks Directive.

v) The Water Frameworks Directive

The Water Frameworks Directive (WFD) provides legal structure to protect and restore clean water across Europe and ensure its long-term, sustainable use (DOE, 2015). This piece of legislation integrates agriculture, industry, and spatial planning, and impacts on, while also being impacted by, many other existing pieces of legislation. The Birds, Habitats, and Nitrates Directives, along with regulations on drinking water, bathing waters, and urban waste are all key factors within the WFD, as well as the MSFD. A major requirement of Member States within the WFD is the preparation of River Basin Management Plans, comprised of three, five year planning cycles. These plans are laid out with the goal of achieving Good Ecological Status (GES) of all waters. Ireland will begin its second cycle in 2017, but is currently 2 years behind schedule and so the next cycle will last 4 years rather than 5. At the time of writing, 63% of Irish coastal waters (1 nautical mile from land (EC, 2003)) are deemed to be in “High” ecological status, with the majority of riverine and transitional waters being in a “Moderate” status. Additionally, 73% of Irish rivers have been classified as “unpolluted” as of the last cycle, which is comparatively better than that of most other European countries. Efficient implementation of this framework, combined with the MSFD, could greatly help with the conservation of the coastal marine environment.

vi) The Marine Strategy Frameworks Directive

Similar to the WFD, the Marine Strategy Frameworks Directive (MSFD) is based on achieving GES, but specifically for marine waters. It further aims to have GES established by 2020 (Marine Institute, 2013). Through State, academic, and private consultancy advice and research, the MSFD aims to apply an ecosystem based approach to the management of human activities while still maintaining sustainability of marine resources for future generations. As part of this ecosystem based approach, several factors are considered under the Directive:

- Biodiversity
- Eutrophication
- Food Webs
- Marine Litter
- Invasive Species
- Exploitation of fish stocks
- Emerging Contaminants
- Seafloor Integrity

Tackling these factors, will help alleviate many of the major pressures being places upon the coastal marine environment. However, before any ecosystem based approach could be undertaken it was necessary to carry out initial assessment of each of the above factors. This was carried out in a 500,000km^2 area surrounding Ireland's coastline. With the major issues identified being exploitation of fish stocks by commercial fishers and nutrient enrichment (including eutrophication) (Marine Institute, 2013). This process is to be re-evaluated every 6 years, with the definition of GES constantly improved. This allows for new information to be incorporated so any and all targets, characteristics, and indicators can be further improved and reviewed.

vii) The Nitrates Directive

Although not directly related to the coastal marine environment, the Nitrates Directive is directly related to one of the aforementioned major issues: eutrophication. This regulation has been in place since 1991, and deals with the protection of water quality from agriculture derived pollution, and the promotion of good farming practices (wwwEnviron). The Nitrates Directive establishes rules and management constraints on the application of livestock manure and fertilisers, through a series of four year Nitrate Action Plans (NAP). It was given legal effect in Ireland as part of the EU Good Agricultural Practice for Protection of Waters. The third NAP came into effect in 2014, with updated and amended policies. These included: the limiting of the amount of manure applied to the land each year, defined high risk time periods where the application is to be forbidden, and the storage capacity levels for animal manures.

In Co. Cork, manure cannot be spread between October 15th and January 12th, based on decisions made by consultation between public bodies, farmers and the EC. Further limitations were put in place based on weather conditions. Fertilisers cannot be spread if land is waterlogged, flooded or at risk of flooding, frozen, or if high rainfall is expected within 48 hours. By sticking to these constraints, farmers have greatly helped reduce the amount of run-off driven eutrophication in Irish waters. In order to meet the growing demands of the dairy and beef industries, intensive farmers have also been allocated an increased allowance of the weight of fertiliser permitted to be

applied to an area of farmland, from 170kg/ha to 210kg/ha annually. Enforcement of this directive is strictly regulated by local authorities, set out by the Department of Agriculture, Fisheries, and the Marine.

viii) The Irish National Biodiversity Action Plan

It is not just the EU that are influencing environmental conservation and protection in Ireland. The Irish government, have created and adopted their own policies. One such policy is the National Biodiversity Action Plan. First launched in 2002, as part of the 1979 Wildlife Act, its 91 Actions integrates all other European and international conservation directives (DAHGI, 2002). This plan defines three levels at which biodiversity conservation can be considered: Ecosystem Diversity, Species Diversity, and Genetic Diversity. A second, amended Biodiversity Action Plan was introduced for the 2011-2016 period with 102 Actions focussing on, not only biodiversity, but also ecosystem services (DAHGI, 2010). Four categories of ecosystem services are defined within the legislation. The first of these is provisioning services, such as food, the second is regulating services, such as climate change, thirdly is supporting services, like nutrient cycling, and finally, cultural services, like recreation. This piece of legislation grants environmental protection both within and outside of designated protected areas.

This legislation demands that environmental protection and conservation is made a priority in governmental decisions. It further aims to increase base knowledge of current environmental issues and threats, promote public awareness and participation in conservation, and to represent Ireland's contribution to international conservation efforts. A third Action Plan will begin formulation in 2016, to come into effect in 2017, taking into account the 6 target areas of the EU Biodiversity Strategy to 2020 (www3NPWS). These 6 targets are:

1) Full implementation of all EU Directives
2) Maintain and restore ecosystem services
3) Increase the contribution of agriculture and forestry to maintaining and enhancing biodiversity

4) Ensuring the sustainable use of fisheries resources
5) Combat invasive, alien species
6) Help avert global biodiversity loss

Through correct and effective implementation of these Action Plans, the state of the Irish coastal marine environment, and the environment in general, will continue to improve. However, without the efficient enforcement, it can all be for nothing. This is where organisations like the National Parks and Wildlife Service are vitally important for continued conservation of Irish biodiversity.

ix) The National Parks and Wildlife Service

The National Parks and Wildlife Service (NPWS) is part of the Heritage Division of the Department of Arts, Heritage, and the Gaeltacht. They oversee areas of:

- Policy and management of Parks and Reserves, Nature Service strategy, Finance and regional operations including enforcement
- Wildlife Acts and EU Directives, "Licensing provisions under the Wildlife Acts, Modernisation of property management, Policy on residential properties in national parks and the Departments Development Applications Unit" (www4NPWS)
- Peatland Policy, Turf compensation and relocation schemes, and Land Designation and Restoration
- "Scientific Support, Biodiversity policy and international issues, CITES and exotic species, Agri-Environment policy and schemes, Marine and aquaculture issues, Education Service and Data management" (www4NPWS)

South West Cork comes under the Southern Division of NPWS, where the Science and Biodiversity Department perform crucial work in the areas of Marine and Habitats, Conservation Systems and Informatics, and Species and Aquatics. Without this work, Irish ecosystems would be without the level of protection said to be needed by governments, scientists and the public alike. NPWS secure the conservation of a

whole range of ecosystems (including the marine) by maintaining and enhancing the native flora and fauna of Ireland. They are key in the designation of SACs and SPAs. They ensure proper implementation and enforcement of EU Policy and Directives, and the ratification of international conventions and agreements. Furthermore, without NPWS it would be increasingly difficult to maintain, manage and develop National Parks and Reserves, like Lough Hyne. Through education, public outreach, and stakeholder engagement, NPWS are also helping to raise awareness for the importance of biodiversity and natural heritage.

It is due to the rigorous workings of government and international policy makers, through services like NPWS that the mounting pressures on the coastal marine environment can be alleviated. Without correct definition and enforcement of environmental policy and legislation, conservation of biodiversity and protection of valuable ecosystem services would not be possible.

Conclusions:

It is clear to see that human activities are continuously placing pressure on the coastal marine environment, and that coastal communities are now experiencing the ramifications of these pressures. For each issue there exists a duality where, on one hand is benefiting the environment, and on the other is a detriment to the people who rely upon the coastal ecosystem. TACs, quotas, gear restrictions, and fishery closures are all contributing to the reestablishment of commercially and biologically sustainable fish stocks. However, additional financial pressures are now being placed upon fishermen and other industries with many opting to seek alternate forms of income. The expanding aquaculture industry is bringing new incomes to coastal areas, but is also causing conflicts with other aspects of society, such as tourism and artisanal fishing. Additionally, excess nutrients and escapees are detrimentally altering the natural ecosystem functions. The ecological status of the coastal marine environment is being constantly improved through pollution reducing measures, yet the development and implementation of said measures are often economically costly. Climate change has now become a recognised priorities by most nations, and several

alleviating measures are now being introduced successfully. However, the issue of climate change is constantly shifting that is thought to be irreversible and can only be mitigated through continuous management efforts combined with reduction of anthropogenic pressures.

In Ireland, and globally, increasing levels of environmental research and education are causing increasing awareness of the importance of the marine ecosystem and its biodiversity. This has led to the raising of many voices, often with differing priorities, that can conflict with traditional practices of cultural importance. Only through efficient and effective communications between policy makers, academics, and the general public can a balanced compromise be found. It is in this way that the coastal marine environment can be made sustainable for future generations, both in South West Cork and around the world.

References:

Alexandratos, N., & Bruinsma, J. (2003). World agriculture: towards 2015/2030: an FAO perspective. *Land Use Policy*, *20*(4), 375.

Althaus, F., Williams, A., Schlacher, T. A., Kloser, R. J., Green, M. A., Barker, B. A., Schlacher-Hoenlinger, M. A. (2009). Impacts of bottom trawling on deep-coral ecosystems of seamounts are long-lasting. *Marine Ecology Progress Series*, *397*(March 2016), 279–294.

Alverson, D.L., Freeberg, M.H., Murawski, S.A., Pope, J.G., (1994). A global assessment of fisheries bycatch and discards*. FAO Fisheries Technical Paper,* 339, 233.

Bax, N., Williamson, A., Aguero, M., Gonzalez, E., & Geeves, W. (2003). Marine invasive alien species: A threat to global biodiversity. *Marine Policy*, *27*(4), 313–

Borges, L., Rogan, E., & Officer, R. (2005). Discarding by the demersal fishery in the waters around Ireland. *Fisheries Research*, 76, 1-13.

Brown, J., & Macfadyen, G. (2007). Ghost fishing in European waters: Impacts and management responses. *Marine Policy*, *31*(4), 488–504.

Cannaby, H. and Hüsrevoglu, Y. S. (2009) Low frequency variability and long-term trends in Irish SST records. *ICES Journal of Marine Science*, In Press.

Cooper, J. A. G., & Pilkey, O. H. (2004). Sea-level rise and shoreline retreat: Time to abandon the Bruun Rule. *Global and Planetary Change*, *43*(3-4), 157–171.

Cosgrove, R., Graham, N., Curtin, R., Moore, S.-J., Kelly, E., & Keatinge, M. (2015). At sea simulation of the operational and economic impacts of the landing obligation on Irish demersal fisheries. *Report to the Discard Implementation Group*, (February), 13.

Cosgrove, R., Cronin, M., Reid, D., Gosch, M., Sheridan, M., Chopin, N., & Jessopp, M. (2013). Seal depredation and bycatch in set net fisheries in Irish waters. *Fisheries Resource Series*, *10*.

Cronin, M., Jessopp, M., Houle, J., & Reid, D. (2014). Fishery-seal interactions in Irish waters: Current perspectives and future research priorities. *Marine Policy*. Elsevier.

Cubero-Pardo, P., & Bastidas, E. A. (2008). *The impact of ecotourism activities on wildlife and sessile benthic species in the Galapgaos Marine Reserve*. *Galapagos Report*.

Culloty, S. C., & Mulcahy, M. F. (2007). *Bonamia ostreae* in the native oyster *Ostrea edulis*: A Review. *Marine Environment and Health Series*, *29*(1649), 1–40.

Cummins, V., O'Mahony, C., & Connolly, N. (2003). Review of Integrated Coastal Zone Management & Principals Of Best Practice. *Science*, 1–84.

Darwin, J. (2008) *Poison in the Well: Radioactive Waste in the Oceans at the Dawn of the Nuclear Age.* Rutgers University Press.

Davenport, J., & Davenport, J. L. (2006). The impact of tourism and personal leisure transport on coastal environments: A review. *Estuarine, Coastal and Shelf Science*, *67*(1-2), 280–292.

Department of the Environment and Local Government (DELG), (2001) Coastal Zone Management, Spatial Planning Unit, Dublin 1.

Department of Agriculture, Food, and the Marine. (2011). *Value for Money Review Fisheries Decommissioning Schemes 2005-2008*.

Department of Arts, Heritage, and the Gaeltacht. (2002). *National Biodiversity Plan - Ireland*.

Department of Arts, Heritage, and the Gaeltacht. (2010). *Actions for Biodiversity 2011-2016 Ireland's National Biodiversity Plan*.

Department of Arts, Heritage, and the G. (2013). *Site Name : Lough Hyne Nature Reserve and Environs SAC*.

Department of Environment. (2015). *Significant Water Management Issues in Ireland. Public Consultation Document*. *Environment, Community and Local Government*.

Derraik, J. G. B. (2002). The pollution of the marine environment by plastic debris: A review. *Marine Pollution Bulletin*, *44*(9), 842–852.

Devoy, R. (2011) Best International Practice for Ireland's Coastal and Marine Governance. UCC. Irish Costal Network. 25/11/2011. www.cmrc.ie/attachments/download/16/Robert%20Devoy.pptx. Accessed 18/05/16

Devoy, R. J. N. (2008). Coastal Vulnerability and the Implications of Sea-Level Rise for Ireland. *Journal of Coastal Research*, *242*(2), 325–341.

Devoy, R., (2003). *Coastal Erosion, from The Encyclopaedia of Ireland*, pp215-216, Brian Lawlor (editor), Gill and McMillan Ltd, Dublin.

Dickinson, J. L., Shirk, J., Bonter, D., Bonney, R., Crain, R. L., Martin, J., Purcell, K. (2012). The current state of citizen science as a tool for ecological research and public engagement. *Frontiers in Ecology and the Environment*, *10*(6), 291–297.

Didham, R.K., Lawton, J.H., Hammond, P.M. & Eggleton, P. (1998). Trophic structure stability and extinction dynamics of beetles (*Coleoptera*) in tropical forest fragments. *Philosophical Transactions of the Royal Society of London: Biological Sciences*, 353, 437–451.

Drake, J.A. & Mooney, H.A. (1989) *Biological Invasions: a global perspective*. John Wiley & Sons. Chichester.

Duffy, J. E. (2003). Biodiversity loss, trophic skew and ecosystem functioning. *Ecology Letters*, *6*(8), 680–687.

EFSA (2009) Scientific Opinion of the Panel on Contaminants in the Food Chain on a request from the European Commission on Marine Biotoxins in Shellfish - Summary on regulated marine biotoxins. *The EFSA Journal of Agricultural and Food Chemistry*, 1306, 1-23.

EPA. (2015). *Water Quality in Ireland 2010 - 2012*.

European Parliament and Council of the European Union. (2013). REGULATION (EU) No 1380/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2013 on the Common Fisheries Policy, amending Council Regulations (EC) No 1954/2003 and (EC) No 1224/2009 and repealing Council Regulations (EC) No 2371/2002 and (EC) No. 639/2004 and Council Decision 2004/585. *Official Journal of the European Union*, *L354*(28.12.2013), 22–61.

European Parliament and Council of the European Union, & Directive, C. (1997). *Commission of the European communities*. *World Patent Information* (Vol. 1).

European Commission (2010). Directive 2009/147/EC of the European Parliament and of the Council on the conservation of wild birds. *Official Journal of the European Union*, *L 20*, 7–25.

Evans, D., & Roma, C. (2006).The Habitats of the European Union Habitats Directive, *173*(3), 167–173.

Evans, S.M., Hunter, J.E., Elizal, Wahju, R.I.(1994) Composition and fate of the catch and bycatch in the Farne Deep (North Sea) *Nephrops* fishery. ICES *Journal of Marine Science,* 51, 155– 168.

FAO (2002) The state of world fisheries and aquaculture, FAO, Sofia.

Feely, R. A., Doney, S. C., & Cooley, S. R. (2013). Ocean acidification: UK Ocean Acidification Programme. *Oceanography*, *22*(4), 36–47.

Furlong, W., Martin, P.M. (2000) Observer deployment in the fishery and regulatory self-enforcement. In: *IIFET Proceedings. Corvallis, OR: International Institute of Fisheries and Trade*.

Guiry, M (2010). 'History of Seaweed in Ireland'. In 'World Seaweed Resources', UNESCO. Ed. A.T. Critchley, M. Ohno. D.B. Largo.

Hall, M. A., Alverson, D. L., & Metuzals, K. I. (2000). By-catch: Problems and solutions. *Marine Pollution Bulletin*, *41*(1-6), 204–219.

Halling-Sørensen, B., Nors Nielsen, S., Lanzky, P. F., Ingerslev, F., Holten Lützhøft, H. C., & Jørgensen, S. E. (1998). Occurrence, fate and effects of pharmaceutical substances in the environment--a review. *Chemosphere*.

Hinder, S. L., Hays, G. C., Brooks, C. J., Davies, A. P., Edwards, M., Walne, A. W., & Gravenor, M. B. (2011). Toxic marine microalgae and shellfish poisoning in the British isles: history, review of epidemiology, and future implications. *Environmental Health : A Global Access Science Source*, *10*(1), 54.

Hoch, M. (2001). Organotin compounds in the environment - An overview. *Applied Geochemistry*, *16*(7-8), 719–743.

Hynes, S., Norton, D., & Corless, R. (2014). Investigating societal attitudes towards the marine environment of Ireland. *Marine Policy*, *47*, 57–65.

Islam, S., Alam, A. K. M. R., & Islam, S. (2010). Analysis of Metal in Wastewater Collected from Three Pharmaceutical Industries Located in Tongi Area of Gazipur District. *Bangladesh Journal of Scientific and Industrial Research*, *45*, 277–282.

Jackson, D., Drumm, A., McEvoy, S., Jensen, O., Mendiola, D., Gabina, G., Black, K. D. (2015). A pan-European valuation of the extent, causes and cost of escape events from sea cage fish farming. *Aquaculture*, *436*, 21–26.

Jessop, M., McAllen, R., O'Halloran, J., & Kelly, T. (2013). *Nutrient and Ecosystem Dynamics in Ireland' s Only Marine Nature Reserve (NEIDIN)*.

Jones, O., Voulvoulis, N., Lester, J., (2001). Human pharmaceuticals in the aquatic environment a review. *Environmental Technology,* 22, 1383-1394.

Kaiser, J. (2010). The dirt on ocean garbage patches. *Science (New York, N.Y.)*, *328*(June), 1506.

Karagiannakos, A. (1996). Total Allowable Catch (TAC) and quota management system in the European Union. *Marine Policy*, *20*(3), 235–248.

Kearney, T. (2013) *Lough Hyne - from Prehistory to the Present*. Macalla Publishing. Ireland.

Krause, J. C., vonNordheim, H., & Bräger, S. (2006). Marine Nature Conservation in Europe 2006. *Procedings of the Symposium*, (May 2006), 107–116.

Kuhn, S., Bravo Rebolledo, E. L., & van Franeker, J. A. (2015). Deleterious effects of litter on marine life. In M. Bergmann, L. Gutow, M. Klages (Eds.). *Marine Anthropogenic Litter* (pp. 75–116).

Lawton, J.H. (1995). *Population dynamic principles. In: Extinction Rates* (Eds Lawton, J.H. & May, R.M.). Oxford University Press, Oxford, pp. *147–163.*

Lewis, R.R., Durkao, M.J., Moffler, M.D., Phillips, R.C. (1985). *Seagrass meadows of Tampa Bay: a review. In: Treat*, S.F., Simon, J.S., Lewis, R.R., Estevez, E.D.,

Mahadevan, S.K. (Eds.), Proceedings, Tampa Bay Area Scientific Information Symposium. Burgess Publishers Co. Inc., Minneapolis, MN, pp. 210-246.

Lewison, R. L., Crowder, L. B., Read, A. J., & Freeman, S. A. (2004). Understanding impacts of fisheries bycatch on marine megafauna. *Trends in Ecology and Evolution*, *19*(11), 598–604.

Lokkeborg, S. (1998). Seabird by-catch and bait loss in long-lining using different setting methods. *ICES Journal of Marine Science*, *55*(1), 145–149.

Lokkeborg, S., & Robertson, G. (2002). Seabird and longline interactions: Effects of a bird-scaring streamer line and line shooter on the incidental capture of northern fulmars *Fulmarus glacialis*. *Biological Conservation*, *106*(3), 359–364.

Lusher, A. L., Hernandez-Milian, G., O'Brien, J., Berrow, S., O'Connor, I., & Officer, R. (2015). Microplastic and macroplastic ingestion by a deep diving, oceanic cetacean: The True's beaked whale *Mesoplodon mirus*. *Environmental Pollution*, *199*, 185–191.

Macfayden, G., Huntington, T., & Cappell, R. (2009). Abandoned, lost or otherwise discarded fishing gear. FAO Fisheries and Aquaculture Technical Paper, 115 pp.

Mack, R. N., Simberloff, D., Lonsdale, W. M., Evans, H., Clout, M., & Bazzaz, F. A. (2005). Biotic Invasions: causes, epidemiology, global consequences, and control. *Ecological Applications*, *86*(4), 249–250.

Marine Institute. (2013). *Ireland's marine strategy framework directive article 19 summary report initial assessment, GES and target and indicators*.

McArdle, J.F., McKiernan, H. Foley, J., & Jones, D.H. (1991). The current status of *Bonamia* disease in Ireland. *Aquaculture* 93, 273-278.

McGinnity, P., Prodöhl, P., Ferguson, A., Hynes, R., Maoiléidigh, N. O., Baker, N., Cross, T. (2003). Fitness reduction and potential extinction of wild populations of Atlantic salmon, *Salmo salar*, as a result of interactions with escaped farm salmon. *Proceedings. Biological Sciences / The Royal Society*, *270*(1532), 2443–50.

McNeil, B. I., & Matear, R. J. (2006). Projected climate change impact on oceanic acidification. *Carbon Balance and Management*, *1*(1), 2.

MERC. (2007). *Surveys of sensitive subtidal benthic communities in Roaringwater Bay and Islands, Lough Hyne Nature Reserve and Environs, Valentia Harbour and Portmagee Channel, Broadhaven Bay*.

Minchin, D. (2007). Aquaculture and transport in a changing environment: Overlap and links in the spread of alien biota. *Marine Pollution Bulletin*, *55*(7-9), 302–313.

Moore, C. J. (2008). Synthetic polymers in the marine environment: A rapidly increasing, long-term threat. *Environmental Research*, *108*(2), 131–139.

Moriarty, M., Pedreschi, D., Stokes, D., Dransfeld, L., & Reid, D. G. (2016). Spatial and temporal analysis of litter in the Celtic Sea from Groundfish Survey data: Lessons for monitoring. *Marine Pollution Bulletin*, *103*(1-2), 195–205.

Morrissey, K., O'Donoghue, C., & Hynes, S. (2011). Quantifying the value of multi-sectoral marine commercial activity in Ireland. *Marine Policy*, *35*(5), 721–727.

Mostofa, K. M. G., Liu, C. Q., Vione, D., Gao, K., & Ogawa, H. (2013). Sources, factors, mechanisms and possible solutions to pollutants in marine ecosystems. *Environmental Pollution*, *182*, 461–478.

Murphy, R.J., Tuthill, R.E., Casey, D., & O'Riordan, R. (unpublished) Abundances of *Nucella lapillus* (L) and *Littorina littorea* (L) as indicators of TBT levels in Cork Harbour and Bantry Bay, Ireland. Master's Thesis, University College Cork.

National Institute for Coastal and Marine Management of the Netherlands (RIKZ) (2004). Living with coastal erosion in Europe: Sediment and Space for Sustainability: PART I - Major findings and Policy Recommendations of the EUROSION project. *Contract*, 57.

Naylor, R. L., Goldburg, R. J., Primavera, J. H., Kautsky, N., Beveridge, M. C., Clay, J., Troell, M. (2000). Effect of aquaculture on world fish supplies. *Nature*, *405*, 1017–1024.

Nolan, G., Gillooly, M., & Whelan, K. (2010). *Irish Ocean Climate and Ecosystem Status Report 2009*. *Ocean Science*.

O'Flynn, C., Kelly, J. and Lysaght, L. (2014). Ireland's invasive and non-native species – trends in introductions. *National Biodiversity Data Centre Series*, (2), Ireland.

OSPAR Commission. (2011). *Annual OSPAR report on dumping of wastes or other matter at sea in 2009*.

Palmer, R., Carson, J., Ruttledge, M., Drinan, E., & Wagner, T. (1997). Gill disease associated with *Paramoeba*, in sea reared Atlantic salmon in Ireland. *Bulletin of the European Association of Fish Pathologists*, 17: 112–114

Pimm, S. L., Jones, H. L., & Diamond, J. (2011). On the Risk of Extinction. Published by : The University of Chicago Press for The American Society of Naturalists. *The American Naturalist*, *132*(6), 757–785.

Purvis, A., Gittleman, J.L., Cowlishaw, G. & Mace, G.M. (2000). Predicting extinction risk in declining species. *Proceedings of the Royal Society of London: Biological Sciences*, 267, 1947–1952.

Raven, J., Caldeira, K., Elderfield, H., Hoegh-Guldberg, O., Liss, P., Riebesell, U., Watson, A. (2005). Ocean acidification due to increasing atmospheric carbon dioxide. *Policy Document*, *5*(12), 60.

Read, P., & Fernandes, T. (2003). Management of environmental impacts of marine aquaculture in Europe. *Aquaculture*, *226*(1-4), 139–163.

Rogan, E., & Mackey, M. (2007). Megafauna bycatch in drift nets for albacore tuna (*Thunnus alalunga*) in the NE Atlantic. *Fisheries Research*, *86*(1), 6–14. http://doi.org/10.1016/j.fishres.2007.02.013

Rogan, E., Penrose, R., Gassner, I., Mackey, M. J., & Clayton, P. (2001). Marine Mammal Strandings 1994 - 1999 A collaborative study for the Irish Sea. *Maritime INTERREG Series*, (8), 1–56.

Ruane, N. M., & Jones, S. R. M. (2013). Amoebic Gill Disease (AGD) of farmed Atlantic salmon (*Salmo salar* L.). *ICES Identification Leaflets for Diseases and Parasites of Fish and Shellfish*, (Leaflet No.60), 6pp.

Ruiz, G. M., Carlton, J. T., Grosholz, E. D., & Hines, A. H. (2015). Global Invasions of Marine and Estuarine Habitats by Non-Indigenous Species : Mechanisms, Extent, and Consequences. *American Zoologist*, *37*(6), 621–632.

Sabine, C. L., Feely, R. A., Gruber, N., Key, R. M., Lee, K., Bullister, J. L., Rios, A. F. (2004). The Oceanic Sink for Anthropogenic CO2. *Science*, *305*(5682), 367–371.

Sea Change (2006). *A Marine Knowledge, Research and Innovation Strategy for Ireland, 2007-2013*. Marine Institute. 172pp.

Sellner, K. G., Doucette, G. J., & Kirkpatrick, G. J. (2003). Harmful algal blooms: Causes, impacts and detection. *Journal of Industrial Microbiology and Biotechnology*, *30*(7), 383–406.

Silvertown, J. (2009). A new dawn for citizen science. *Trends in Ecology & Evolution*, *24*(9), 467–71.

Stokes, K., O Neill, K., & Mcdonald, R. (2006). Invasive Species in Ireland. *Report to Environment & Heritage Service and National Parks and Wildlife Service by Quercus, Queens University*.

Summerfield, M.A., (1991) *Global Geomorphology*. 537 pp. Longman, Singapore.

Sweeney, J., Brereton, T., Byrne, C., Charlton, R., Emblow, C., Fealy, R., Holden, N., Jones, M., Donnelly, A., Moore, S., Purser, P., Byrne, K., Farrell, E., Mayes, E., Minchin, D., Wilson, J. & Wilson, J. (2003) *Climate Change: Scenarios and Impacts for Ireland*. Environmental Protection Agency, Johnstown Castle, Wexford, 229pp.

Teuten, E. L., Saquing, J. M., Knappe, D. R. U., Barlaz, M. A., Jonsson, S., Björn, A., Takada, H. (2009). Transport and release of chemicals from plastics to the environment and to wildlife. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *364*(1526), 2027–45.

Theodorou, J.A. (2002). Current and future technological trends of European seabass– seabream culture. *Reviews in Fisheries Science,* 10, 529–543.

Thom, B.G. & Hall, W. (1991). Behaviour of beach profiles during accretion and erosion dominated periods. *Earth Surface Processes and Landforms,* 16, 113-127.

Thomas, D.N. (2002). *Seaweeds*. The Natural History Museum, London.

Thresher, R. E., & Kuris, A. M. (2004). Options for managing invasive marine species. *Biological Invasions*, *6*(3), 295–300.

Twiner, M. J., Rehmann, N., Hess, P., & Doucette, G. J. (2008). Azaspiracid shellfish poisoning: A review on the chemistry, ecology, and toxicology with an emphasis on human health impacts. *Marine Drugs*, *6*(2), 39–72.

Tyler, C. R., & Jobling, S. (2008). Roach, Sex, and Gender-Bending Chemicals: The Feminization of Wild Fish in English Rivers. *BioScience*, *58*(11), 1051.

UN. (2010). Resumed Review Conference on the Agreement Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks.

United Nations Economic Commission for Europe. Convention on Access to Information, Public Participation in Decision-Making and Access To Justice in Environmental Matters, Aarus Convention 25 (1998).

VanAtten, A.S. (1997). *Comparison of fishermen catch reports to observer data*. In: McVea T.A., Kennelly, S.J. (Eds), *Proceedings of the fifth international fisheries observer conference—15–18, May, 2007, Victoria, British Columbia, Canada*. Cronulla, Australia: NSW Department of Primary Industries, Cronulla Fisheries Research Centre of Excellence, 412.

van Sebille, E., England, M. H., & Froyland, G. (2012). Origin, dynamics and evolution of ocean garbage patches from observed surface drifters. *Environmental Research Letters*, 7, 044040.

Walsh, M., & Watson, L. (2011). A market analysis towards the further development of seaweed aquaculture in Ireland. *Irish Sea Fisheries Board, Dublin*, *Part 1*, 1–48.

Walters, C. J., Watson, R., Zeller, D., Pauly, D., Christensen, V., Guénette, S., Zeller, D. (2002). in World Fisheries. *Nature*, *41*(8 August), 689–695.

Warner, S. (2004). An analysis of the indirect effect of national marine fisheries service observers on the logbook reporting of prohibited species catch. In: NMFS. Proceedings of the third international fisheries observer conference. US Department of Commerce, NOAA Technical Memos, NMFS-F/SPO-64, 2004. p. 192.

Watkins, S. M. (2008). Neurotoxic Shellfish Poisoning. *Marine Drugs*, *6*(3), 430–455.

Watson, R., Gelchu, A., & Pauly, D. (2001). Mapping Fisheries Landings with Emphasis on the North Atlantic. *Mapping Fisheries Landings*, 1–11.

Wilcox, C., Van Sebille, E., & Hardesty, B. D. (2015). Threat of plastic pollution to seabirds is global, pervasive, and increasing. *Proceedings of the National Academy of Sciences of the United States of America*, *112*(38), 11899–11904.

Wild, C., Hoegh-Guldberg, O., Naumann, M. S., Colombo-Pallotta, M. F., Ateweberhan, M., Fitt, W. K., & van Woesik, R. (2011). Climate change impedes reef ecosystem engineers. *Marine and Freshwater Research*, 62, 205–215.

Woodworth, P. L., Gregory, J. M. and Nicholls, R. J. (2005). *Long term sea level changes and their impacts. The global coastal ocean: multiscale interdisciplinary processes*, Robinson A. R. and Brink K. H., (Eds.), Cambridge, Massachusetts, 715-753.

Woolf, D. K., Challenor, P. G., & Cotton, P. D. (2002). Variability and predictability of the North Atlantic wave climate. *Journal of Geophysical Research*, *107*(C10), 3145.

Web References:

Citation	Site	Date Accessed
www1	http://www.historyireland.com/early-modern-history-1500-1700/the-spanish-basque-irish-fishery-trade-in-the-sixteenth-century/	17/04/2016
www2	https://bantryblog.wordpress.com/	26/04/2016
www3	http://cleancoasts.org/marine-litter/	30/04/2016
wwwEnviron	http://www.environ.ie/water/water-quality/nitrates/nitrates-directive	02/05/2016
wwwIFI	http://www.fisheriesireland.ie/Invasive-species-list/zebra-mussel.html	13/04/2016
wwwOSPAR	http://www.ospar.org/about/history	28/04/2016
www1SFPA	http://www.sfpa.ie/Sea-FisheriesConservation/FisheriesStatisticsandQuotaUptake/CurrentQuotaUptake.aspx	21/04/2016

www2SFPA	http://www.sfpa.ie/Sea-FisheriesConservation/Legislation/QuotaClosures.aspx	21/04/2016
www1NPWS	http://www.npws.ie/protected-sites/sac	29/03/2016
www2NPWS	http://www.npws.ie/nature-reserves/cork	29/03/2016
www3NPWS	http://www.npws.ie/legislation/national-biodiversity-plan	07/05/2016
www4NPWS	http://www.npws.ie/about-npws	05/05/2016