ALMA MATER STUDIORUM
UNIVERSITY OF BOLOGNA

SCHOOL OF SCIENCE

Laurea Magistrale in Analisi e Gestione dell'Ambiente
Curriculum in Water and Coastal Management

ASSESSMENT OF THE SUSTAINABILITY AND RESILIENCE OF CORK HARBOUR AGAINST CLIMATE CHANGE USING THE CONCEPT OF CIRCLES OF COASTAL SUSTAINABILITY (CCS)

Supervisor:
Dr. Alice Newton

Presented by:
Wint Mon Swe

Co-supervisor:
Dr. Martin LeTissier

Table of Contents

List of Tables

List of Figures

Acronyms

AEP	Annual Exceedance Probability
CCS	Circle of Coastal Sustainability
CSO	Central Statistics Office
DIN	Dissolved Inorganic Nitrogen
EPA	Environmental Protection Agency
EQR	Ecological Quality Ratios
EU	European Union
GIS	Geographic Information System
GVA	Gross Value Added
HMFG	Harbour Management Focus Group
ICES	International Council for the Exploration of the Sea
IPCC	Intergovernmental Panel on Climate Change

LTA	Long Term Average
MRFS	Mid-Range Future Scenario
NAF	National Adaptation Framework
NGOs	Non-Governmental Organisation
NMP	National Mitigation Plan
NUTS	Nomenclature of Territorial Units for Statistics
OECD	Organisation for Economic Co-operation and Development
OPW	Office of Public Works
SAC	Special Areas of Conservation
SDG	Sustainable Development Goal
SLR	Sea Level Rise
SPA	Special Protection Areas
UN CC:Learn	United Nations Climate Change Learning Partnership
WFD	Water Framework Directive

Acknowledgement

I would like to express my special thanks to Prof Dr. Alice Newton, and my co-supervisor Dr. Martin Le Tissier for their endless support and their guidance throughout this project. I would also like to thank Natália Alencar for her useful advice in kickstarting this project.

I wish to show my appreciation to the future Earth Coasts members Dr. Sebastian Ferse and Hannah Jansen, and ZMT NO CRISES project members Dr. Marion Glaser and Lol Dahlet, for their attention and expertise they shared during my internship periods. All collaborators and professors at the University of Bologna and University of Cadiz, that provided the help and support throughout my study periods.

I would like to thank the Erasmus Mundus preprogramme for the funding during these 24 months, and my WACOMA colleagues for enabling me to fully enjoy my academic experiences in Italy, Spain, and Portugal.

Last but not least, I would like to give my deepest gratitude to my family for always giving me their utmost support and love.

Abstract

Coastal areas are where many socioeconomic and ecological processes come together to provide important services that drive the economy, social and culture of the community. With climate change impacts becoming more apparent, the sustainability and the resilience of the community is crucial when these climate extremes occur. This paper discusses on the sustainability and resilience of Cork Harbour using recently established sustainability framework – Circles of Coastal Sustainability – stemming from Circles of Sustainability but tailored for coastal zones. Cork Harbour was evaluated to be in 'good' status in terms of sustainability, also putting it in a resilient position against climate impacts. The shortcomings encountered using the framework include difficulty in choosing locally relevant indicators and complication in scoring the chosen indicators.

[Chapter 1 - Introduction]

This thesis is in partial fulfilment of the requirements for the Erasmus Mundus master's in water and Coastal Management. It focuses on sustainability and resilience of Cork Harbour in the context of predicted climate change and flooding, an important issue for coastal managers and planners.

1.1 Hypothesis, overarching aim, research objectives, and main research questions

1.1.1 Hypothesis

The study is based on the hypothesis that an interdisciplinary assessment of coastal social-ecological systems can support decision-making in adaptive management in response to climate change.

1.1.2 Overarching aim

The main aim is to assess the resilience of the system – Cork Harbour – against climate-change weather extremes and its sustainability performance, using a holistic assessment of sustainability. The outcome of the assessment will identify and focus attention on the aspects (i.e., environmental, social, economy or governance) identified as requiring improvement to increase resilience and sustainability.

1.1.3 Research objectives

1. To assess the sustainability and resilience of Cork Harbour as a coastal social-ecological system.
2. To identify the shortcomings that potentially (restrain) the sustainability and resilience achievements by using CCS framework.
3. To evaluate the assessment method used in order to improve it in a future iteration.

1.1.4 Research questions

The main research question is "Can CCS framework be integrated into legal instruments for climate change resilience and climate change adaptation?"

Other supporting research questions include:

1. Can we identify, assess and analyse the locally appropriate indicators that can be used in a Social-Ecological Sustainability Assessment?
2. What are the difficulties and shortcomings in using CCS framework for resilience assessment?
3. What are the main issues facing Cork Harbour in the context of climate change?
4. How can this be communicated clearly to decision makers, planners, coastal managers, and other relevant stakeholders?

1.2 Introduction

In 1938, the first observation of a change in the earth's atmospheric temperature was first identified by a British engineer Guy Callender. He linked the warming of the atmosphere with an increase in CO_2. However, it was not until 1975 that the term "global warming" was first put in use by a US scientist Wallace Broecker (Black, 2013). In 1988, Intergovernmental Panel on Climate Change (IPCC) was formed to address and assess evidence on climate change. Since then, IPCC has published six assessment reports where climate related data are assessed through available information from published sources (Intergovernmental Panel on Climate Change, 2018).

The latest report – the sixth assessment report – by the IPCC detailed the observed impacts from human-induced climate change. Due to the interdependence of climate, ecosystems and biodiversity, and human societies, frequent and extreme weather events have caused losses and damages to nature and people (Masson-Delmotte, et al., 2021). Climate-driven impacts have caused losses on both economies and livelihoods, as well as changed cultural practices around the world. These changes are expanding and are challenging the resilience of some ecological and human systems (Pörtner et al., 2022). The adaptive capacities of environment and human systems are key players in preventing vulnerable people and marginalised group of people at risks. **Coastal risks**, especially due to sea level rise, is predicted to increase by at least one order of magnitude by the end of this century; cities and settlements by the coasts are anticipated to receive the highest concentration of impacts – on ecosystems, livelihoods, infrastructures, food security, cultural and natural heritage (Pörtner et al., 2022). **Compound hazards** and transboundary risks will furthermore exacerbate existing

stressors and become major threats for coastal cities. This is where the resilience of the system becomes a deciding factor of placing a coastal system on a climate change vulnerability scale.

Community resilience with factors from different dimensions (i.e., environment, social, economic and governance) is needed for dealing with long-term crises such as reduced availability of natural resources and environmental change.

1.2.1 Resilience

Resilience has many different meanings in the literature; Lei et al. referred to resilience as the capacity of a system restructuring itself and the speed of recovery (Lei, et al., 2014). In contexts of climate change and natural disasters, resilience is the capacity to withstand and recover from such events. It also indicates the ability and capacity of the system for transformation (Pelling, 2011) (Masson-Delmotte, et al., 2021). Resilience as defined in IPCC sixth assessment report is "the capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure while also maintaining the capacity for adaptation, learning and transformation" (Pörtner et al., 2022). This is the definition that was used in this study.

Climate resilient should be supported by international cooperation and government of all levels in corporation with civil society, scientific and education bodies, media, investors, and businesses; and by developing partnerships with traditionally marginalized groups including women, youth, indigenous people, local communities, and ethnic minorities (Masson-Delmotte, et al., 2021). High levels of inequity make the society less resilient to climate change risks. Effective mitigation and adaptation actions are important for the societies and ecosystems to adapt to not only current but also further coastal risks. This all depends on the coping ability of the ecosystems, extent of social vulnerability, societal choices, institutional support, and governance practices (Pelling, 2011).

1.2.2 Assessing sustainability

The Brundtland report coined the term *sustainability* as "meeting the needs of the present without compromising the ability of future generations to meet their own needs". The concept takes on a holistic approach with the integration of three central pillars that make up core concepts of the sustainability: economic, social and environment (Brundtland, 1987)

(Pradere, et al., 2022). Another familiar term that comes hand in hand with *sustainability* concept is *sustainable development*. Sustainable development is now a term that is widely used and enforced in not only development strategies but also in policy instruments at all levels: local, national, regional and international (Juwana, et al., 2012) (UN General Assembly, 2015).

Climate hazards are direct drivers of many issues that are already existing in the system. Most often, climate change related issues are linked and overlapping with sustainability issues; both concepts are regularly integrated into climate and adaptation policies. A familiar set of 17 sustainable development goals (SDGs) recognised by the United Nations General Assembly in 2015 are now the backbone of sustainable development planning and in decision-making processes (UN General Assembly, 2015). Incorporating the UN's SDGs in development strategies reinforce the concepts of resilience and vulnerability against climate change extremes (Aly, et al., 2022). The significant role of sustainable development in resilience and disaster-risk management is not unfamiliar (Derissen, et al., 2011) (Redman, 2014). It is more than ever important with increasing frequency and severity of climate change disasters, especially concerning with human and economic damages (Barros & Field, 2014) (Aly, et al., 2022).

However, sustainability is a vague term that is bias against people, and issues relating to it can be defined in many ways, are unique to individuals, are associated to other problems, and there is no single best definitive solution or a well-established agenda for sustainability issues (Dijk, et al., 2017). Effective adaptation plans with clear objectives are necessary in order to address current and future climate disaster risks and in improving resilience of the system. Many 'rich' nations or developed nations usually devise high-level climate policies, however the likelihood of effective adaptation 'on-the-ground' is arguable, especially with the rate of climate change (O'Mahony, et al., 2015). Crucial process is the application of effective management plans derived from clear view of what the shortcomings (vulnerabilities) are in each (dimension) and avoid maladaptation (Pörtner et al., 2022). Effective and practical management (adaptation) strategies require sufficient knowledge of status of the area/system and the outcome of previously placed adaptation strategies. The definition of sustainability used in this study is the generally familiar definition mentioned in the Brundtland report (Brundtland, 1987).

1.3 Indicators-based approach

Sustainability assessment is an approach that aims to support decision-making in environmental, policy and social contexts (Sala, et al., 2015) (Dijk, et al., 2017). One approach is the development of sustainability assessment tools using an indicator-based evaluation to measure sustainability (Juwana, et al., 2012) (Halkos & Argyropoulou, 2022) (Gunnarsdottir, et al., 2022). The term 'indicator' is very fluid. They are variables that measures entities and can carry wide range of meanings depending on the context; for example, in context of environmental indicators, a presence or an absence of a certain species could be an indicator factor. One of the well fit meanings of indicator is "a measure or component from which conclusions on the phenomenon of interest can be inferred" (Heink & Kowarik, 2010). (Heink & Kowarik, 2010) provides a list of many meanings of the term 'indicator' in their research. The fluidity of the term gives room for biasness. Thus, the selection of indicators is crucial and should be selected through literature-based review and existing frameworks (Juwana, et al., 2012). In addressing sustainability and sustainability assessment, indicators should be able to evaluate unsustainable conditions of the study area. This is where most challenges come in picture, i.e., the process of selecting relevant indicators that best fit the locality of the study area and establishing a connection to the final objectives of sustainability performance. Characteristics of sustainability indicators are 1) sensitivity to change in time, 2) sensitivity to change across space or within groups, 3) predictive ability, 4) availability of reference or threshold values, 5) ability to measure reversibility or controllability, 6) appropriate data transformation, 7) integrative ability, and 8) relative ease of collection and use (Liverman, et al., 1988).

[Chapter 2 – System Characteristics]

2.1 System Location

This section consists of the system information of Cork Harbour socio-ecological system. Cork Harbour is a sheltered naturally deep-water harbour located at the mouth of the River Lee in the southern coast of Republic of Ireland (INFOMAR, 2020). Located in County Cork, which is one of the 26 counties in Ireland, Cork Harbour is one of the significant employment hubs in Ireland with pharmaceutical plants, and oil terminal and refinery, power station and former steel plant and fertiliser plant (INFOMAR, 2020). It is a complex system that surrounds other estuaries and inlets such as the North Channel, the Douglas River Estuary,

inner Lough Mahon, Monkstown Creek, Lough Beg, the Owenboy River Estuary, Whitegate Bay and the Rostellan and Poulnabibe inlets (National Parks and Wildlife Service, 2014).

FIGURE 1: CORK HARBOUR SYSTEM BOUNDARY.

The upper part of Cork Harbour consists of Lough Mahon, suburbs Trivoli and Douglas while the lower Cork Harbour consists of three significant islands: Great Island, Haulbowlie and Spike Island (INFOMAR, 2020). Among the urban cities around the harbour, Cork City is the most economically significant and is located nine miles upstream on the northwest corner on the River Lee; other main urban developments in the area apart from Cork City are Midleton, Cobh and Carrigaline (fig. 1).

Great Island, situated between the two channels of River Lee, is the largest island in Cork Harbour connected to the mainland by a causeway and rail line. A historical town named Cobh (known as Queenstown until 1922) can be found at the south of Great Island overlooking the harbour. Apart from its historical sites, Cobh is also known for being a final port of RMS Titanic before it sunk.

Haulbowline Island hosted Irish Steels, Ireland's only steelworks, until its closure in 2001. The island is located between Cobh (to the north) and Ringaskiddy (to the south), and the East

Tip of the island contains about 650,000 m^3 of steelworks waste that was deposited on a sand pit over a 40-year period of operation. In 2011, Irish Government signed off €40 million for clean-up of the toxic waste site at the East Tip (Conroy, 2011). Haulbolwine Island is now home to the headquarters of the Irish Navel Service who are tasked with routine patrols for fishery protection and the interception of the illegal cargoes.

Ringaskiddy used to be a fishing village but is now a centre of transport and industrial activities; the village is now one of the largest employment hubs in pharmaceutical sector; for example, *Pfizer* which has been in operation in Ringaskiddy for more than five decades and has recently invested €300 million investment in Irish operations. Access to the village is from Haulbowline Island via a bridge across another island called Rocky Island. Ringaskiddy hosts the only training centre of Merchant Navy personal in Ireland, called The National Maritime College of Ireland.

Spike Island is located right in the centre of Cork Harbour beside Haulbowline Island and is known of its 200-year-old star shaped fort called Fort Mitchel. The fort was the largest prison in mid-19th century and then became a base for the British army, succeeding to a base for Irish Army and then was operational as juvenile centre until its closure in 2004. Fort Mitchel is now a tourist attraction that offers walking trails around the fort and the island, as well as boats from and to Cobh.

Whitegate Oil Refinery is in the east of Spike Island and is connected by causeway to the mainland. Whitegate Refinery is now acquired by Irving Oil in 2016 and has been in operation since 1959 and supplies 40% of Ireland's petroleum needs.

System boundary. Fig.1&2 show map of Cork Harbour with a system boundary (red box). The system boundary, of ~ $2000km^2$, is established based on the flood maps produced by the OPW. The flood-risk map used on fig.3 is of Mid-Range Future Scenario (MRFS) at a medium-probability. MRFS accounts for 20% increase in rainfall, 20% increase in peak flow and of 0.5m SLR (Office of Public Works, n.d.). Medium-probability accounts for 1-in-a 200 chance event (AEP 0.5%). This is a more localised flood scenario compared to the IPCC predictions; IPCC SSP 2-4.5 (intermediate scenarios) predicts around 0.20m +/- 0.006m. OPW flood-risk maps are localised to country level and are with higher confidence. Thus, they were chosen as a reference for the system boundary. As flood-risk map does not capture the full scope of what

will be impacted from the risk, the system boundary of interest which touches the flood-risk extents in Cork Harbour region was created. The boundary encompasses the socio-economic criteria that are immediately and directly linked to harbour.

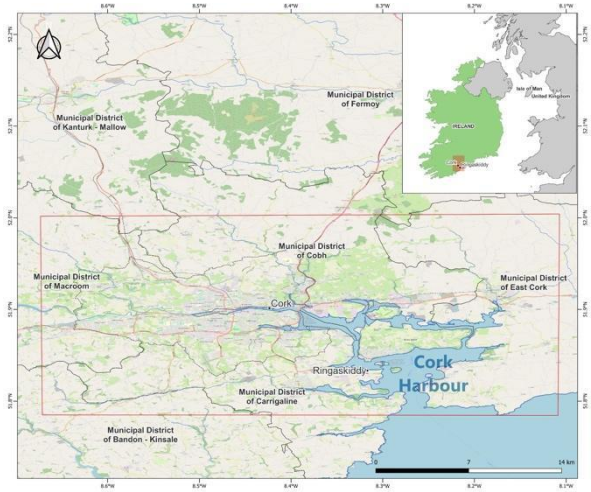

FIGURE 2: CORK HARBOUR MAP WITH A SYSTEM BOUNDARY. SYSTEM AREA MAKES UP ABOUT APPROXIMATELY $2000km^2$.

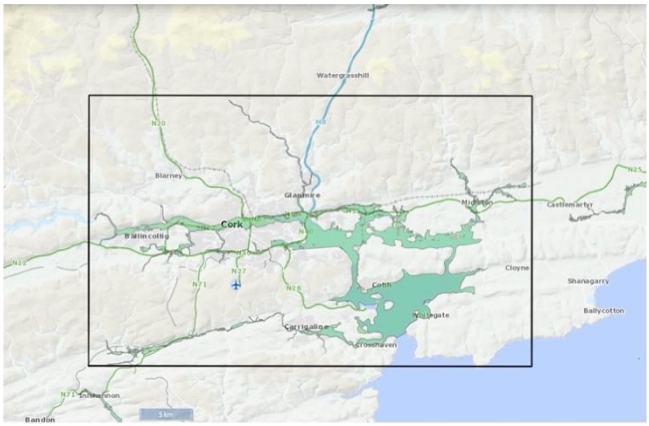

FIGURE 3: CORK HARBOUR MRFS FLOOD-RISK SCENARIO MAP WITH A SYSTEM BOUNDARY (BLACK BOX).

2.2 Climate Change and exacerbated environmental problems

As a coastal area as well as home to rapidly growing urbanisation, Cork Harbour experiences environmental problems resulting from different pressures. Some examples of the most generalised problems are eutrophication, water pollution, contaminated land, land-use conflict etc. (Cummins, n.d.). Among these environmental problems, flooding is the most prevalent issue that County Cork and whole of Ireland frequently experience, especially in urban areas around Cork Harbour that have been developed in coastal plains (INFOMAR, 2020). Just between 1841 and 1988, a total of 292 recorded floods have occurred in Cork City. The most severe flooding took place in 2009 where major damages were caused to commercial and residential buildings in Cork City, followed by another major flood event taking place in February 2014 resulting in 50 million euros damage and these flooding events will only increase in severity and frequency.

With climate-change projections indicating increased risk of flooding, many areas of importance will be vulnerable to flooding (Desmond, et al., 2008). The main issue to focus on in relation to climate change is flooding due to changes in precipitation patterns, storm patterns and sea level rise (IMCORE, 2011). Ireland's climate has changed, and this change is in line with global and regional climate trends. The climate variables or pressures in all of Ireland

include air temperature, heatwaves, cold snaps, precipitation, extreme weather events, soil temperatures, ground- and surface- water runoff, surface freshwater temperatures, sea temperatures, sea chemistry, waves and surges and sea level rise (Desmond, et al., 2008).

Risks related to climate change that are in relation to Cork Harbour and associated cities that are identified in Cork City Council Climate Change Adaptation Strategy are: hydrology, rainfall, sea level rise, sea temperature, surface air temperature, waves, and surges. These risks all inevitably result in flooding – groundwater, pluvial, fluvial, and coastal – and coastal erosion.

Sea level rise (SLR). A recently published Intergovernmental Panel on Climate Change (IPCC) sixth assessment report stated the predictions of SLR to 0.38 m increase by 2100 in SSP 1-1.9 and up to 0.77 m increase for SSP 5-8.5 scenario (Masson-Delmotte, et al., 2021). SLR is a primary issue in coastal zones regardless of urban, agricultural, or natural systems. In the past decades, SLR of 3.6 mm per year was recorded for 2006-2015; in Ireland, a SLR of 3.5 cm per decade has been observed (Environmental Protection Agency, n.d.).

Rising precipitation and changes in precipitation patterns. River flooding and inundation of poorly drained land have been linked to precipitation patterns. Resulting outcome is ground and surface-water runoff leading to nutrient leaching, poaching of ground, pollution, and soil erosion. In the period 1981-2010, Ireland has experienced an increase in average annual precipitation of 60 mm or 5% nationwide. Environmental Protection Agency Ireland has predicted increase in frequency of heavy precipitation events especially in Winter and Autumn seasons (Environmental Protection Agency, n.d.).

Rising land and sea temperatures. An increase in air temperature of 0.7˚C has been recorded since 1890; an average of 0.06˚C per decade. In addition, there was an observed 0.85˚C rise in Irish coastal sea since 1950 and 2007 was warmest year in Irish coastal record (Desmond, et al., 2008). Apart from expansion of sea water, warmer temperatures can also impact on resilience of ecological systems; for example, arrival of new pests and warmer sea temperatures putting stress on aquaculture. Increased temperatures also have resulted in increase in frequency and intensity of storms in the last few decades in Ireland (Geological Survey Ireland, 2021).

Apart from water related environmental problems; air pollution is also another issue that has been on the rise. Environmental Protection Agency of Ireland produced a report on

composition and sources of air particulate air pollution performed between 2007 and 2008 at Trivoli Docks and Haulbowline Naval Base in Cork Harbour. Traffic from vehicles was the largest single-source contributor, accounting for 23% of ambient PM 2.5 at the Trivoli Docks site. During winter times, domestic solid combustion (DSF) was the most significant source contributing 75% to organic carbon and 30% to PM2.5 (O'Connor, et al., 2011).

2.3 Climatic Conditions

Cork County has a temperate climate; cold, rainy winters and mild, rainy summers. The climatic conditions are mainly influenced by the Atlantic Ocean to the west. Weather can be very uncertain, and it is normal to have 'four seasons in a day' in Cork. Temperature in summer can reach up to 20˚C and as low as 2˚C to 3˚C in winter. Like all of Ireland, Cork County receives an average of 73 days of relatively heavy rain per year (Pure Cork, n.d.).

2.4 Geomorphology

The coastline geomorphology is a mix of shallow cliffs, intertidal mudflats, reedbeds, shingle and rocky foreshores. Apart from the natural architecture, built infrastructures are also found along the harbour coastline (Cummins, n.d.). The Harbour itself is the result of post-glacial sea level rise; it was once a river valley. Surrounding terrain is underlain with anticline core sandstones that form uplands and syncline cores of softer limestone forming east-west trending valleys; much of the flooding areas are dominated by softer limestones (INFOMAR, 2020).

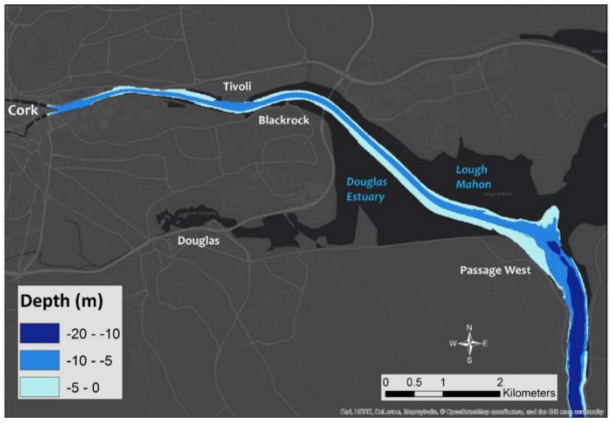

FIGURE 4: NAVIGATIONAL ROUTE AND DEPTH OF CORK HARBOUR. (SOURCE: INFOMAR)

To provide access to cruise liners, the harbour has a dredged channel, and the navigational route (fig.4) goes around the islands of Spike and Haulbowline before heading upstream towards Cork City (INFOMAR, 2020). The navigational route starts to get narrower and shallower (to less than 10 m) once passed Passage West and into Lough Mahon. This makes navigation difficult due to shallow waters and exposed mudflat (INFOMAR, 2020).

Roche's point marks the entrance of the Harbour where the more erosion resistant rock outcrop in the middle of the channel splits the channel into two directions. Although most of

the harbour is shallow with only a few meters deep, the deepest part of the harbour are channels formed from erosion by rivers and tidal flows. A sandbar called Spit Bank can be seen in the east of Haulbowlie Island at low tide; Spit Bank lighthouse is located at the very spot to assist with navigational purposes (INFOMAR, 2020).

2.5 Hydrology

The harbour encompasses a total surface water body area of 100 km^2 with a tidal range of 0.6 - 4m varying across the harbour (Port of Cork Company, 2021). The riverine input to the harbour is from the Lee, the Owenacurra, and the Owenabue. River Lee, with the Iniscarra dam controlling the freshwater inputs, flows through Cork City, and the much smaller River Owenacurra and River Owenabue flow through Midleton and Crosshaven, respectively (INFOMAR, 2020). Cork Harbour itself is tidal all the way to the edge of Cork City but the lower main harbour is brackish, a mixing zone for sea water and river water; freshwater from the Owenabue can be detected in the Harbour mouth. Up to 23% of the water in the estuary flows to and from the sea twice a day during spring tides; freshwater does not enter the estuary in summer but in fall, up to 65 m^3 of freshwater enters the estuary from River Lee alone (Van Oord Dredging & Marine Contractors, 2012). Table.1 shows hydrological characteristics of Cork Harbour.

TABLE 1: CORK HARBOUR MAIN CHARACTERISTICS. *SOURCE: ECI ENVIRONMENTAL CHANGE INSTITUTE, NATIONAL UNIVERSITY OF IRELAND.*

Estuary area	8.585 hectares
Estuary length	17.17 km
Maximum width	6.14 km
Width at mouth	1.65 km
Main channel width at mouth	1.65 km
Maximum depth	29 m
Maximum depth at mouth	29 m
Tidal prism	150 x 106 m3
Volume	643 x 106 m3
Ratio prism to volume	0.23
Tidal range (spring)	4.2 m
Tidal range (neap)	2.1 m

2.6 Economy

The Port of Cork is the main port serving the County Cork and it has berthing facilities at Cork, Trivoli, Ringaskiddy and Cobh along Cork Harbour (Port of Cork Company, n.d.). Quays in Cork City are mainly used for grain and oil transport; Trivoli provides container handling for oil, ore, livestock and a roll on-roll off terminal; Ringaskiddy operates as a deep-water terminal and is used for passenger and car ferry; Cobh has a deep-water quay used as a terminal for cruise ships (Port of Cork Company, n.d.). Apart from the berths owned by The Port of Cork Company, there are private berths that are associated with industries such as oil (Whitegate), grain (Passage West), cargo (Rushbrooke), and naval (Haulbowline).

Cork Harbour's GDP per capita is consistently higher than that of the national average (Cork Chamber, 2021). Leading expertise in the region are pharmaceutical expertise, biotech and medtech. Apart from these, tourism industry and energy industry contribute to the economy of Cork Harbour; the marine leisure activities in 2016 alone brought total estimated value of €10.94 million providing 29 direct jobs and 290 indirect jobs (Lenihan & McGuirk, 2017). In 2019 alone, cruise ships brought about 200,000 passengers to Cobh; Spike Island received 75,000 visitors in a year before the pandemic. Cork Harbour has an annual resident capacity of 555 berths and 1035 moorings (Lenihan & McGuirk, 2017).

Cork Harbour is on its way to become a more resilient and sustainable economy for the well-being of the residents. Ireland is committed to developing offshore wind – development of 30GW of floating winds – which would provide the country with opportunity to meet net zero emissions by 2050. This will also pave way for international investments in Ireland. Cork Harbour plays an important role to this transformative development in facilitating Ireland to low-carbon society while supporting a resilient economic recovery. The harbour is an existing place with expertise and infrastructures suitable for offshore wind farms in terms of its location, existing port capacities, supply-chain readiness, strategic designations, and human capital (Cork Chamber, 2021). Ireland has a target of using 70% of electricity from renewable energy by 2030 and offshore wind industry will help to achieve this target as well as provides new skilled jobs. As of now, the economy directly related to Cork Harbour has population of 71,910 and 29,171 jobs. However, Cork County Council is expecting to double this by 2040 with increase in 49% in population, 72% in jobs and 51% in housing units; a GDP growth to € 12.4 bn from €4.5 bn in 2040.

2.7 Ecology and Biodiversity

2.7.1 Habitats and Special Protection Areas

Cork Harbour is an internationally important wetland site (RAMSAR), providing habitats for about 20,000 wintering waterfowls during the non-breeding seasons making it one of the top ten important wintering sites in Ireland and internationally. Designated as a RAMSAR site on the 7th June 1996, the site is significant for internationally important Black-tailed Godwit and Redshank (National Parks and Wildlife Service, 2014). The habitats in the harbour are mainly intertidal mudflats and reed-beds (Cummins, n.d.); the intertidal mudflats are usually mixed sediment to sandy mud with polychaetes and oligochaetes (National Parks and Wildlife Service, 2014). A range of macro-invertebrates can be found in these mudflats, such as *Macoma balthica*, *Scrobicularia plana*, *Neresis diversicolor*, and *Corophium volulator* (National Parks and Wildlife Service, 2014). Although Green algae are common along the mudflats, the intertidal flats such as Rossleague and Belvellly are dominated by Common Cordgrass (*Spartina spp.)* in the harbour. Salt marshes can be found scattered through the system and they provide important environment for high tide roosting birds.

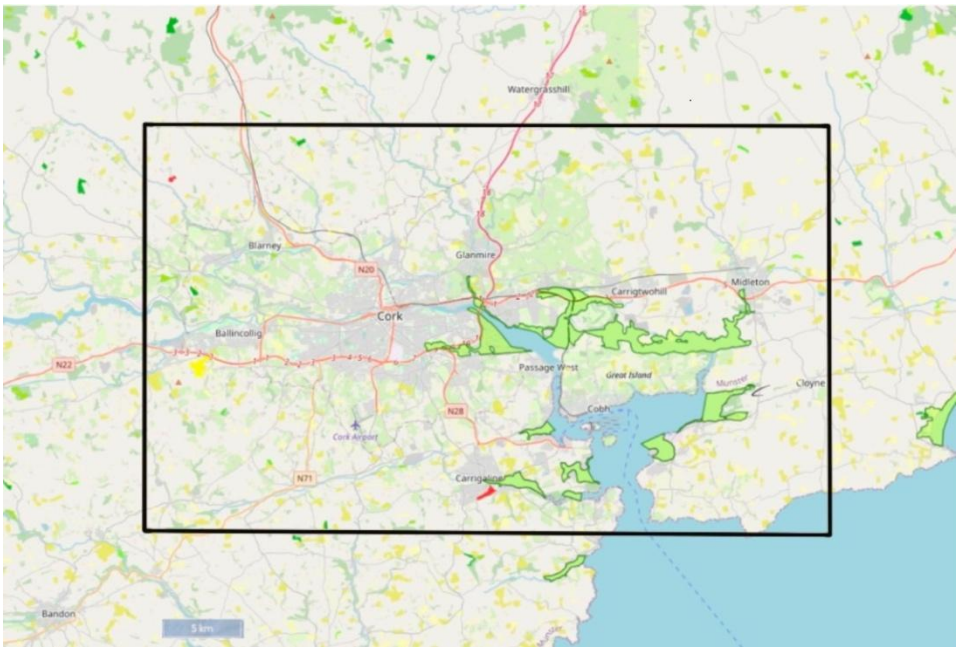

FIGURE 5: SPECIAL PROTECTION AREAS IN CORK HARBOUR. (SOURCE: ENVIRONMENTAL PROTECTION AGENCY)

Figure 5 maps the Special Protection Areas in Cork Harbour (in green), and the table under the appendices (Table.A1) lists species for Cork Harbour SPA, plus rank of importance on national, regional, and county scale. The information below was taken from Conservation

and Supporting Document of Cork Harbour Special Protection Agency (National Parks and Wildlife Service, 2014).

The baseline data are from the years 1995/1996 – 1999/2000 and are the 5-year mean peak counts of this period. National Importance Rank refers to the importance of the site for non-breeding populations of the Site of Community Importance (SCI) species during the baseline period relative to other sites in Ireland; Regional Importance Rank refers to the importance of the site for non-breeding populations of the SCI species during the baseline period relative to the other sites within the southern region of Ireland; County Importance Rank refers to the importance of the site for non-breeding populations of the SCI species during the baseline period relative to the other sites within County Cork (National Parks and Wildlife Service, 2014).

2.8 Governance Structure

2.8.1 The Port of Cork Company

The Port of Cork Company is a statutory authority responsible for the management, control, operation and development of the Port of Cork in accordance with the Harbours Act 1996. Before the Port of Cork was established, The Cork Harbour Commissioners were in charge for almost 183 years; they were active from 21st September 1814 to 3rd March 1997 (Port of Cork, n.d.). After the establishment of the Harbours Act 1996, re-valued assets were transferred to Port of Cork Company along with the full authority.

The Port of Cork Company is a semi-state company responsible for the commercial running of the harbour and for navigation in the port. A semi-state company or agency is a state-owned enterprise that is technically commercially run, which are beneficially owned, either completely or partially, by the Irish Government.

2.8.2 Cork City Council and Cork County Council

Cork City Council is an authority acting as a local government for Cork City in Ireland, and Cork County Council for the county of Cork; the councils are governed by the Local Government Act 2001. The shared responsibilities include housing and community, roads and transportation, urban planning and development, amenity and culture, and environment of the whole County Cork. In 2019, the boundary of Cork City Council was extended, merging-in the territory formerly part of Cork County Council (Local Government Act 2019 (Transfer Day)

Order 2019, 2019). The final extension of Cork City Council does not include Cork Harbour region. Nevertheless, the responsibilities of city council are closely linked to county council. Cork County Council takes on broader and county wide roles; as a county council, the board also leads some of the regional managements such as Cork National Roads Office, Climate Change Adaptation Planning – Southern Region, National Food Safety Laboratory Service, etc.

2.8.3 The Oireachtas

The Oireachtas is the legislature of Ireland and consists of the President of Ireland and the two houses of the Oireachtas, Dail Eireann (lower house) and Seanad Eireann (upper house). The Oireachtas has power to legislate, propose changes to constitution, allow international agreements to become part of the domestic law, etc. Thus, the Oireachtas plays a very essential role in passing the laws and regulating internal legislations that are influential on the sustainability of Cork Harbour.

2.8.4 European Union

The European Union (EU) is an economic and political union consisting of 27 countries located in Europe. The member states of the EU practices an internal single market established through a standardised system of laws. Common policies in the EU ensures free movement of people, goods, services, and capital within the internal market and maintain these polices on trade, agriculture, fisheries, and regional development (European Union, 2021). EU is established on treaties and has the legal powers to enforce legislations which directly affect all member states. There is a principle of supremacy where member states and their national courts are required to enforce the treaties that they have ratified (European Union, 2021) which are achieved through regulations and directives. A ‘regulation’ is a binding legislative act, and it must be applied across the EU; a ‘directive’ is a legislative act that sets out a goal that member states must achieve (European Union, 2020). By having these regulations and directives, EU’s influence on national laws of member states is significant.

[Chapter 3 – State of the Art]

3.1 State of the Art

Cork Lower Harbour Main Drainage Scheme was initiated in response to the decades long discharge of raw sewage equivalent of 40,000 wheelie bins into Cork Harbour every day (Irish Water, n.d.). €144 million investment was made by Irish Water in this project to ensure that wastewater from agglomerations of towns and villages in Cork lower harbour is collected and treated before safe discharge to the sea. By 2017, equivalent of 20,000 wheelie bins of raw sewage were treated daily and by 2019, the number increased to 30,000. 7 km of sewage pipes and 5 pumping stations spread across in Cobh which are linked to Monkstown and other agglomerations through sewer pipes under the Lee Estuary. All the raw sewage collected are sent to Shanbally Wastewater Treatment plant for treatment before its released to the sea (Irish Water, n.d.).

As a region with great economic importance and environmental importance, Cork Harbour has numbers of strategic plans and policies in place to ensure the sustainability and growth of local economy and community. Cork County Development Plan 2014 which was a six-year development plan that came in effective in 15th January 2015 remained in force until 2020. The plan set out overall planning and sustainable development strategy for the county which was consistent with the National Spatial Strategy 2002-2020 and the South-West Regional Planning Guidelines 2010-2022 (Cork County Council, n.d.). A newly prepared Cork County Development Plan is in preparation for the period 2022-2028 to guide the future development of the county (Cork County Council, 2021).

As for the previous coastal management studies specifically focused on Cork Harbour, the 'Integrated Management and Adaptation Strategies for Cork Harbour, Ireland' is part of the case studies conducted under IMCORE project that focus on coastal adaptation strategies in 2009 (IMCORE, 2011) (Climate-ADAPT, 2016). The project's objective was to develop an ICZM framework and a local climate change adaptation strategy. Steps were taken to establish a strategic alliance between the local authority and multidisciplinary academic experts; Harbour Management Focus Group (HMFG) was set up to implement the management strategy. After this project, the strategic alliance group and the HMFG are now working towards the preparation of an Adaptation Strategy for Cork Harbour, focusing on flood management by 2030.

3.1.1 Cork County Council Climate Change Adaptation Strategy (2019-2024)

The new EU Strategy on Adaptation to Climate Change aims to forge a climate-resilient Europe. Climate-related events have affected economic activities such as agriculture, aquaculture, tourism, etc. Not only do they have economic impacts, but they also pose risks to food security, exacerbates existing social inequalities, and threatens cultural heritage. Under the 2013 EU Adaptation Strategy, all Member States are to have a national adaptation strategy or plan, which have been mainstreamed into local policies and adaptation plans (Climate-Adapt, 2021).

Climate Action Plan 2019 focuses on mitigation measures by which Ireland can reduce its emissions from sectors outside the EU's Emission Trading System by 2030 (Department of the Taoiseach, 2020). There are 183 individual actions, which are specific to and/or relate to local authorities, over 12 sectors working towards decarbonisation. Ireland is on its way of transition to a low-carbon, climate-resilient, and environmentally sustainable society by 2050. Climate Action Plan commits great responsibilities and challenges to local authorities in climate change mitigation (Department of the Taoiseach, 2020).

Under the National Adaptation Frameworks (NAF), local authorities were assigned with producing a Climate Adaptation Strategy; Cork County Council Climate Change Adaptation Strategy focuses on a series of actions that Cork County Council introduces to adapt and mitigate existing and future climate risks the county faces (Cork County Council, n.d.). This adaptation strategy will be the central instrument to achieve the goals towards a low carbon, climate resilient and sustainable environment. The document was established on seven high level goals: Local Adaptation Governance and Business Operations; Infrastructure and Built Environment; Land-use and Development; Drainage and Flood Management; Natural Environment, Built and Cultural Heritage; Community, Health, and Wellbeing; other sectors and agencies.

3.1.2 Cork City Council Climate Change Adaptation Strategy (2019-2024)

Cork City Council has also produced a Climate Change Adaptation Strategy (2019-2024) which is a primary instrument at a local level aiming to reduce and manage the increasing risks associated with climate change. This strategic plan is an acknowledgement to the fact that climate change has caused, is causing and will continue to cause impacts into foreseeable future and is part of the Ireland's NAF and is in accordance with the provisions of the Climate Action

and Low Carbon Act 2015 (Cork City Council, 2019). The two main goals of Cork City Council Climate Change Adaptation Strategy are to make Cork City as climate-resilient as possible by lessening the impacts of current future climate change-related events and to pro-actively engage all citizens on climate actions – climate change, climate change adaptation and climate change mitigation. The objectives are placed across the seven thematic areas [1]and were prepared through a public consultation process. These high-level themes were developed through four guiding principles: mainstream adaptation, informed decision-making, building resilience and capitalising on opportunities.

On the international level, the strategic plan was developed within the context of United Nations Sustainable Development Goals, United Nations Framework on Climate Change, The Kyoto Protocol, 2013 EU White Paper for more climate resilient Europe, and 2015 Paris Agreement. On top of these international protocols, Cork City is also signed to Global Covenant of Mayors for Climate Change.

In European Context, the 2013 EU Strategy on Adaptation to Climate Change encourages all member states to adopt comprehensive adaptation strategies. Republic of Ireland has several frameworks and action plans that guide local adaptation strategies with their development schemes. Some examples are 2012 National Climate Change Adaptation Framework, 2014 National Policy Position on Climate Action and Low Carbon development, the National Mitigation Plan (NMP), the NAF 2018, and Climate Action Plan 2019 – To Tackle Climate Breakdown. Within the regional context, two key themes of Cork City Council strategic plan directly relate to a Regional Spatial and Economic Strategy for the Southern Region that is being prepared by The Southern Regional Assembly for the period 2019-2031.

Cork City Council Climate Change Adaptation Strategy states the measures that have been put in place by Cork City Council. One of them is the Major Emergency Plan 2017 that ensures early warning systems are placed and appropriate actions are taken to deal with major emergencies; examples of early warning systems in Cork City include electronic river gauge, a Flood Early Warning System for the river Lee and Coastal Surge warning protocol for Cork Harbour. Other measures for strategic adaptation include Severe Weather Plans, raising awareness through existing social media channels, maintaining, and developing relationships with important stakeholders and 3rd level institutions, etc.

[1] The seven thematic areas are local adaptation governance and business operations; infrastructure and built environment; land use and development; drainage, water and flood management; nature, natural resources and cultural infrastructures; citizen safety, health and wellbeing; partnerships with other sectors and agencies.

[Chapter 4 – Methodologies]

4.1 Circles of Coastal Sustainability Methodology

This section explains the two methodologies applied in this study; the first half of the section (section 4.1) explains the methodology on choosing indicators and the second half (section 4.2) explains the scoring methods for each chosen indicator.

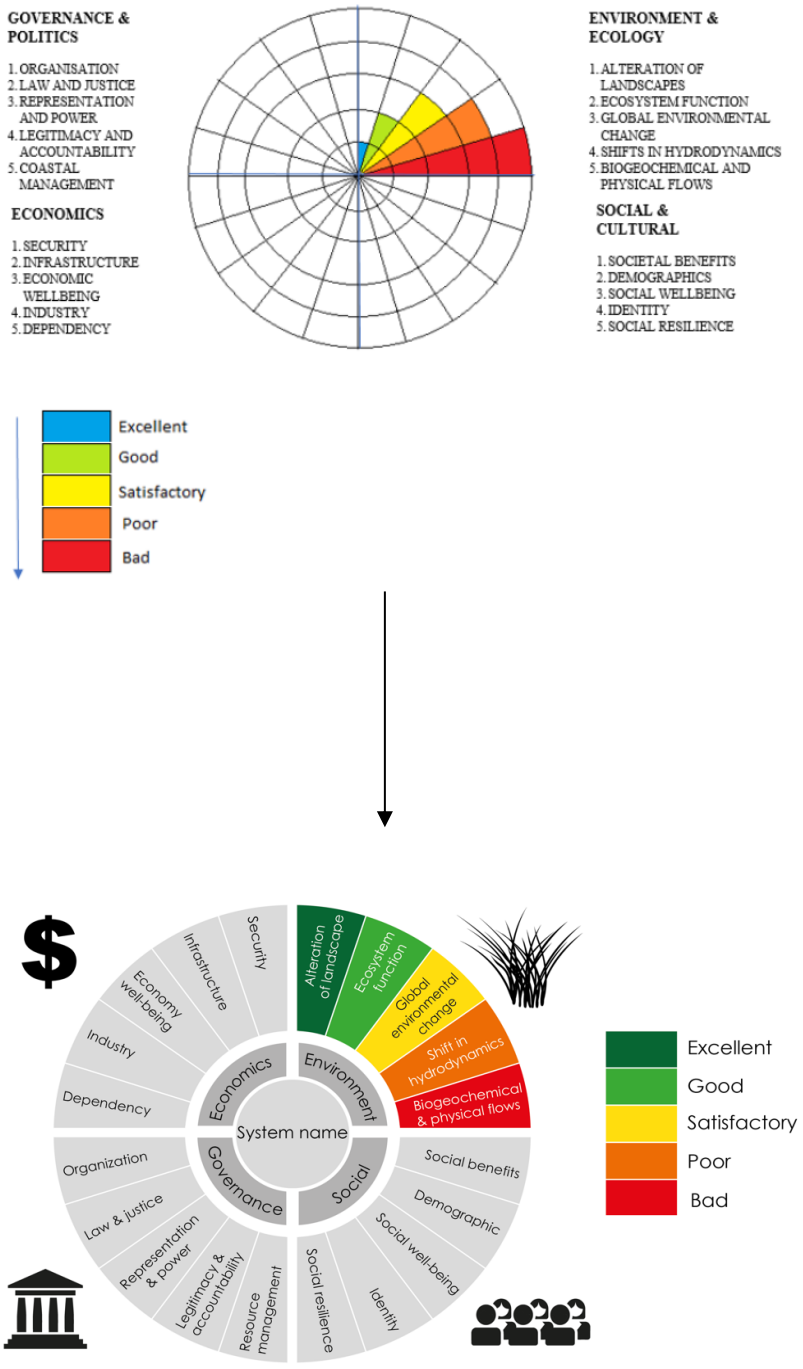

FIGURE 6: A REDESIGNED GRAPHICAL REPRESENTATION OF CCS FRAMEWORK.

Circles of Coastal Sustainability (CCS) framework (fig. 6), stemming from Circles of Sustainability but tailored for coastal zones, incorporates four interdependent boundary dimensions: Environment and Ecology, Social and Cultural, Economics, and Governance and Policy (Alencar, et al., 2020). The CCS includes categories across four dimensions that utilise indicators for coastal sustainability assessment. In the CCS, the categories were proposed in a way that the indicators can be of different types and subjected to interpretation of locality of the study area and can represent any levels of complexity. The chosen indicators classified the scores of the categories under each dimension, which are later graphically represented in a sustainability scale. This framework is applied to a local study area – Cork Harbour – in the Republic of Ireland and explored further on the issues faced during the assessment. This framework was chosen over other sustainability frameworks such as Ostrom and DAPSI(W)R(M)[2] because CCS framework undertakes holistic approach by incorporating socio-ecological elements from omnidirectional approach.

The figure above (fig. 6) shows the graphical representation of CCS framework; a slightly altered graphical representation is designed for Cork Harbour study area. The new graphical representation still carries the five categorical weighing system but with a change in blue to dark green colour for 'excellent' status. The pie chart was also redesigned in a way that it is more user-friendly and clearer for interpretation of the data for stakeholders. The following sub-sections explain the chosen indicators in more details.

4.1.1 Environment and Ecology dimension

Alteration of Landscape

1. **Type of land change on land.** This data was taken from CORINE landcover-change dataset from 2012 to 2018. CORINE Landcover Change data set is part of the COPERNICUS pan-European landcover change data series. This land monitoring service shows different land cover changes over the from 1990 until the recent year, 2018. The data set shows 34 different land-cover types and is ideal for monitoring changes over the years. This dataset is the Irish national CORINE change 2012-2018 dataset, covering the Republic of Ireland, which will be integrated into a seamless

[2] DAPSI(W)R(M) stands for = Drivers, Activities, Pressures, State, Impacts, Welfare, Responses, and Measures.

CORINE 2012-2018 landcover change map of Europe (Environmental Protection Agency, 2022).

2. **Land reclamation extent.** The data for this indicator was taken from Cork Harbour Draft Study and this land reclamation of the harbour was from after 1934. Even with the harbour's long history and extensive built heritage, 70% of the land developed were first developed from 1930s onwards and 17% since the mid-1990s. From 1934 to 1995, the average rate of land development was 2.02 km^2/decade and the average rate of land reclaimed is 0.34 km^2/decade. From 1995 to 2005, the average rate of land development was 4.02 km^2/decade and the average rate of land reclaimed is 0.36 km^2/decade. Based on these data, more than 25% of the intertidal areas will be reclaimed by 2030 (Cork County Council, 2011) (fig.7).

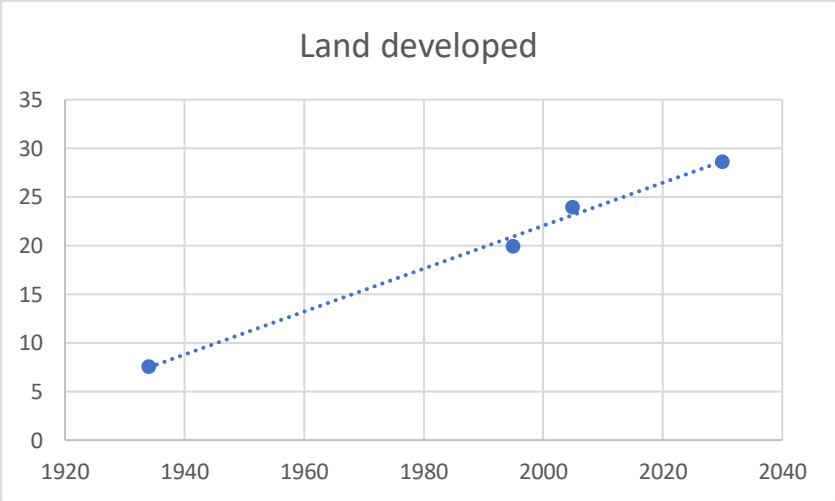

FIGURE 7: PROJECTED RATE OF LAND DEVELOPED OVER THE PAST YEARS AND FOR FUTURE YEARS.

Ecosystem functions

1. **Biodiversity richness.**

   Three protected areas were chosen as an indicator for measuring biodiversity richness. Cork Harbour is an important system with protected areas like SPAs, RAMSAR, and SACs. The protected areas not only protect the vulnerable species or species of international and local importance, but they also indicate the credibility of the environmental governance present in the area. Due to the overlapping protected areas between SPAs and RAMSAR site, RAMSAR site was not included to avoid double counting.

Special Protection Areas are designated areas under the EU Birds Directive where member states select the most suitable sites for birds of vulnerable species listed in Annex I of the Birds Directive and/or are wetlands of international importance for migratory waterfowl (European Commission, n.d.) (National Parks and Wildlife Service, 2014).

Special Areas of Conservation is a designation under the EU Habitats Directive to protect natural habitats that are considered to be under serious threat. Cork Harbour SAC in the Great Channel covers habitats such as mudflats, sandflats, and Atlantic salt meadows (National Parks and Wildlife Services, n.d.).

2. **WFD waterbody status.** The indicators for this sub-category consists of four waterbody types: coastal, river, transitional and groundwater. The data results were recorded in accordance with European Communities (Water Policy) Regulations 2003 (Sl No. 722/2003). As part of the EU Water Framework Directive, the statuses of the waterbodies are the best fit indicators to be used in the CCS assessment.

Global Environmental Change

1. **Sea level rise.** There are different versions of SLR data available – for past and future, global and local. Historical data of SLR specific to Cork Harbour was available from 1842 and 2019; this data was used due to its localized certainty and mean sea level rise was found to be 40 cm from the period of 1942 to 2019 (Pugh, et al., 2021).

2. **Precipitation pattern.** Precipitation in total rainfall (mm) taken from Roches Point[3] from 2019 to 2021 compared to the Long-term Average (LTA). LTA data is average for the climatological long-term-average reference period of 1981-2010 (MET eireann, 2022).

3. **Temperature change.** There are three indicators for measuring temperature: mean air temperature, mean 10 cm soil temperature and global solar radiation. They are all indicators towards temperature change/global warming effects. Among the three, mean

[3] Roche's Point lighthouse is located at the entrance to the Cork Harbour and marks the start of the harbour.

air temperature was chosen. Mean temperature in degrees Celsius taken from Roches Point from 2019-2021was compared to the LTA (MET eireann, 2022).

Shifts in Coastal Dynamics

1. **Tides.** The tidal range of spring tide and neap tide and tidal stability at the harbour was chosen as an indicator for this sub-category. Tidal range is at 4.2m for spring tide and 2.1m for neap tide. Tidal stability was observed over a period of 177 years (Edwards & Hogarth, 2021).

2. **Sediment cycles.** Erosion rates for East of Cork Harbour (1970's and 2006 data) and West of Cork Harbour (1970's and 2000 data) were used as an indicator to measure sediment cycle/pattern of the harbour. East of Cork Harbour has mean annual erosion rate of approx. 0.3 m/year; West of Cork Harbour has mean annual erosion rate of approx. 0.25 m/year (RPS Group, 2011). The dataset available were the most precise dataset for the harbour and were chosen over other available data.

Biogeochemical and physical flows

1. **Nitrogen.** Nitrogen levels are generally considered as one of the primary limiting nutrients in coastal waters; its concentration affects/controls the growth of algae and aquatic plants. For nitrogen value, winter dissolved inorganic nitrogen values in estuarine and coastal water from 2018-2020 was used as an indicator. The data was taken from a report produced by EPA 'Water Quality in 2020: An Indicators Report' (Trodd, et al., 2021). 4 testing points show 1% to 50%; 3 points show -49% to -15%; 2 points show >50%. Thresholds range from between 2.6mg/l N in freshwater to 0.25mg/l N in fully saline waters. DIN concentrations above these thresholds can indicate pollution.

2. **Phosphorus.** For phosphorous value, winter molybdate reactive phosphorus values in estuarine and coastal waters from 2018-2020 was used as an indicator. (Trodd, et al., 2021). 2 testing points show <-50%; 6 points show -49% to -15%. Thresholds range from between 0.060mg/l P for fresh to intermediate salinity waters to 0.040mg/l P for full salinity waters.

4.1.2 Social and Culture

Societal benefits

1. **Goods and Services.** Ecosystem services related to coastal resources are taken as indicators for this sub-category.[4]Total aquaculture value of Cork County in 2015 is €30.8 million (Norton, et al., 2018).

Demographics

1. **Education.** Education is a powerful tool that can change the people's attitudes and behaviours. Education empowers and motivates the young; in the classroom, young people can be informed the impact of global warming and learn how the importance of climate change adaptation (United Nations, n.d.). According to the survey "People's Climate Vote", on climate change carried out by UNCC:Learn, people with university degrees or were attending university were more likely to accept that climate change is a global emergency (UN CC:Learn, 2021). For the assessment of social resilience by education level, 'retention rates of secondary schools' was used as an indicator (Central Statistics Office, 2016). Retention Rates of Pupils in Second Level Schools in Cork County in 2018 is 98.2% for first year entrants who sat the junior certificate and 92.1% for first year entrants who sat the leaving certificate.

2. **Social class.** The regions are divided to nine regions in which the study area falls into South-West region. Percentage of homeless persons was one of the indicators included in the report for UN SDG Goal 1: No Poverty; the same indicator was used to measure social class. Percentage of homeless persons in 2019 for South-West region is 8.3% of the total region (Central Statistics Office, 2020).

Social wellbeing

1. **Bathing beaches.** The quality of the beaches was used as an indicator in a sense that it improves the social quality in terms of amenity value. The two beaches – Fountainstown (Beaches.ie, 2022) and Inch Strand (Beaches.ie, 2022) - that are designated as bathing beaches were in both excellent qualities.

[4] Total aquaculture values include all the services and economics from the aquaculture in general.

2. **Water quality.** Public water supply was the indicator taken for the measure of water quality available for the public. The degree of water quality was crucial when coastal related events affect the public and the consequences that come with it, such as saltwater intrusion or contamination of groundwater sources. The data was taken from 10 stations within cork harbour and averaged (Cork County Council, 2016).

3. **Health.** Healthy population was one of the most significant rewards of promoting community resilience (Castleden, et al., 2022). The health status of Cork County overall has 89.5% of people with good health status. Approximately 83.6% of the people in Cork City are in good health status. This is the second lowest percentage in the country (Central Statistics Office, 2017).

Identity

1. **Sense of place.** Cork Harbour is a place with rich complexity of natural and cultural heritage. Although this sense of identity does not directly associate to resilience of the system in relation to climate change, the cultural importance and its significance is assumed to raise incentives values for actions towards mitigation and adaptation towards climate change (McCarthy, 2019).

Social resilience

1. **Vulnerability.** Socio-demographic main indicators are health status and ageing. In this study, age structure was taken as a way to measure the vulnerability. This indicator was considered to be one of the indicators with degrees of uncertainty due to conflicting evidences found in the literature.

4.1.3 Economics

Security

1. **Livelihoods.** Coastal communities that are dependent on coastal resources are exposed to economic vulnerability especially when it relates to coastal risks and disasters. The indicator used to measure the dependence of coastal communities on coastal resources is the direct GVA from Ireland's ocean economy and its growth over the years (Tsakiridis, et al., 2019). However, due to the difficulties of getting exact GVA for the

system area, a proxy indicator the whole of Ireland was used instead. This established uncertainties to a certain degree.

2. **Gender.** Overcoming gender inequality is one of the crucial components of adaptive capacity. It plays a role in allowing populations to adapt to increasing climate impacts. To measure this, the 'proportions of managers, directors and senior officials who are female in South-West region in 2017' was chosen as an indicator for this sub-category (Central Statistics Office, 2019).

3. **Employment patterns.** Looking from economic prosperity point of view, areas concentrated as economic zones or importance (aka urban settings) are more likely to obtain advantages that give easier access to safe shelters, more timely dissemination of warnings, quicker post-disaster aid, and better construction with stricter building codes (Meyer, 2014). Linking the economic prosperity to the job density, indicator used here to measure the employment patterns is the 'distribution of job in Cork Harbour region compared to the rest of the country' (fig. A1) (Cork County Council, 2019).

Infrastructure

1. **Energy supply.** UN SDG 7 is dedicated towards access to affordable, reliable, sustainable and modern energy for all. Having access to materials and technologies enhance the life quality and make the households/buildings more resilient to threats from natural disasters, as well as assist in recovery quickly from such disasters (HUD User, 2017). The indicator chosen for this was 'the percentage of population with oil central heating in 2016' where the data was extracted from Ireland's Central Statistics Office (Central Statistics Office, 2019).

2. **Transport.** Different transportation means having different carbon footprints. The amount of carbon footprints produced by transportation system was used to measure the contribution towards climate change. The data was taken from the Cork County Development Plan Review: Economy and Employment Background document No. 6 (Cork County Council, 2020). Five categories of transport modes were extracted from the document: (1) on foot, bicycle, bus, train; (2) driving cars; (3) motorcycle; (4) passenger in car; (5) work vehicles; the document lists on foot, bicycle, bus, and train as sustainable transport modes.

3. **Access.** This sub-category measures the access to public transport services by the population. Ease of access and the readily availability of transport services not only improve individual's life quality but also community's quality of life (Mattson, et al., 2021). To measure this sub-category, 'population by frequency of services offered by nearest public transport stop' was used as an indicator. The data represents whole of Cork County which adds uncertainty to the credibility of the indicator (Central Statistics Office, 2016).

4. **Tourism.** Tourism sectors contribute greatly to economic and can be a driving force towards economic development. However, tourism sector is also vulnerable to climate change (UNWTO, n.d.). Climate change also threatens the destinations that tourism relies on and the sustainable and resilient development of the travel and tourism sector. Travel and Tourism competitiveness index was used to measure the tourism sub-category for economics dimension. The index measures three pillars: (1) regulatory framework, (2) business environment and infrastructure, and (3) human, cultural, and natural resources (Calderwood & Soshkin, 2019).

Economic wellbeing

1. **Equality.** Inequality in income among the population creates unequal effects faced by the population; poorer community facing more intense impacts than the wealthy community. For the equality among the populations, GINI index is used to measure the income equality of this sub-category.

2. **Income.** Another sub-category to reinforce the category on a more regional level, 'consistent poverty rate South-West region' was used as an indicator to measure this sub-category. The data was produced for the SDG goals track in Ireland (Central Statistics Office, 2018).

Industry

1. **Renewable energy.** Renewable energy is one of the changes that the society can enforce to mitigate the causes of rising temperatures. Renewable energy sources do not emit carbon dioxide and other greenhouse gases that contribute to global warming and

climate change. Relying on renewable energy also is an action in transitioning towards fuel-free energy sources when fossil fuels are becoming a finite source. Wind energy is one of the bigger sources of renewable energy sources in Ireland. The percentage contribution of the wind farms from the system area to the central source is used as an indicator for this sub-category. The percentage of energy supply were taken from Crocane Wind Farm and Cork Lower Harbour Energy Group's Wind Developments in Ringaskiddy.

2. **Extractive.** Extractive goods (sources) in the coastal areas are mainly coastal energy and marine ecosystem services. Cork region offshore capture fisheries value were approximately €1.0 – 5.0 million (Norton, et al., 2018).

Dependency

1. **Resources.** The dependent on the coastal resources was determined by the percentage breakdown of jobs by industrial groups (Table. A3) (Cork County Council, 2020).

4.1.4 Governance and Policy

Organisations

1. **Civils and NGOs.** The number and diversity of both international and national organisations present for the environmental aid in the area is used as an indicator for this sub-category. The number of member organisations in the Irish Environmental Network was chosen as an indicator (IEN, n.d.)

Law and Justice

1. **Legislations.** The credibility of legislations over the protected areas is examined here for this sub-category, the number of protected areas as per the importance of species present. This is to look at the competency of the government and the legislations placed that are in-line with international and European directives. The harbour area is home to many important species that are of both national and international importance and the protected areas are placed in accordance.

2. **Enforcement.** Enforcement on coastal regulations was measured by number of adaptation strategies in place. According to the OECD Environmental Performance of

Reviews of Ireland, enforcement and compliance promotion are well co-ordinated, but non-compliance levels are relatively high (OECD, 2021).

Representation and Power

1. **Gender.** Well balanced gender representation in the governmental positions is crucial for just representation of power in terms of gender equality. To measure this balance, the indicator 'Percentage of seats in local government held by women in South-West region in 2019' was used (Central Statistics Office, 2019); the same indicator was used to measure the progress of SDG 5 in Ireland. Empowering women is one of the keys to climate-resilient society given their lack of access to essential resources, such as land, finance, or information; this factor is particularly relevant in developing countries.

Legitimacy and Accountability

1. **Voice and accountability.** Voice and Accountability refers to the perceptions of the extent to which a country's citizens can participate in selecting their government, as well as freedom of expression, freedom of association, and a free media (World Bank, 2020).

2. **Control of corruption.** Control of corruption refers to the perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests (World Bank, 2020).

Resource management

1. **Management.** The management category here is strictly focused on aquaculture and foreshore management. The presence of acts and regulations, licenses placed for extractive activities in the system coastal zone was an indicator for this sub-category (Table. A4).

4.2 Scoring System

4.2.1 Environment and Ecology

Alterations of Landscape

CBD's Aichi Biodiversity *Target 5* is to reduce the rate of loss of natural habitats to half, and greatly reduce degradation and fragmentation (Convention on Biological Diversity, 2020).

1. **Type of land change on land.**

Corine Landcover change was used to assess the sub-category landcover change. Taken from CORINE landcover change 2012-2018, CORINE Landcover Change 2012 – 2018 is the 2018 update of the COPERNICUS pan-European landcover change data series. This dataset is the Irish national CORINE change 2012- 2018 dataset, covering the Republic of Ireland, which will be integrated into a seamless CORINE 2012-2018 landcover change map of Europe. The dataset is based on interpretation of satellite imagery and national in-situ vector data (Environmental Protection Agency, 2022). The scoring system below (Table. 2) was used to score this indicator.

Low-confidence indicator: This indicator has no reference data adequate to establish a quantitative scoring system. Thus, it is qualitatively evaluated and is an indicator with low confidence.

2. **Land reclamation extent.**

Land reclamation extent was used as an indicator for land change along the shore/shoreline. The data was taken from Cork Harbour Draft study and this reclaimed land data of the harbour was from after 1934. The position of shoreline-change over time, in response to natural processes and human intervention. Despite the harbour's long history and extensive built heritage, 70% of developed areas adjoining it were first developed from the 1930s onwards and 17% since the mid-1990s. From 1934 to 1995, the average rate of land development was $2.02\ km^2/decade$ and from 1995 to 2005, the average rate of land development was $4.02\ km^2/decade$. From 1934 to 1995, the average rate of land reclaimed is $0.34\ km^2/decade$ and from 1995-2005, the average rate of land reclaimed is $0.36\ km^2/decade$ (Cork County Council, 2011). The same scoring method (Table. 2) used for assessing landcover change is applied for intertidal reclaimed area (fig.7).

TABLE 2: CCS SCORING METHODOLOGY FOR LAND CHANGE.

Bad	90% change in loss of natural habitats or crucial habitats that provide essential services
Poor	70% change in loss of natural habitats or crucial habitats that provide essential services
Satisfactory	50% change in loss of natural habitats or crucial habitats that provide essential services
Good	30% change in loss of natural habitats or crucial habitats that provide essential services
Excellent	0% change in loss of natural habitats or crucial habitats that provide essential services

Ecosystem Function

De Groot et al. defined ecosystem functions as 'the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly' (de Groot, et al., 2002). Based on this definition, biodiversity richness and waterbodies quality are used to definite ecosystem functions.

1. **Biodiversity richness.**

Biodiversity can be seen as an insurance of ecosystem service delivery (Jacobs, et al., 2013). Ecosystem functions, such as carbon storage and preventing land-use changes, are stabilised, and diversified by a higher biodiversity (Eastwood, et al., 2013). Biological diversity boosts the functioning of ecosystems and their ability to maintain functioning under stresses or disturbances ensures the resilience of the ecosystem and the delivery of services.

Convention on Biological Diversity's Aichi Biodiversity Targets come into play in this sub-category, especially *Target 15* – i.e., enhancing ecosystem resilience for climate change mitigation and adaptation through conservation and restoration (Convention on Biological Diversity, 2020).

Aichi Biodiversity *Target 11* – i.e., protecting and conserving coastal and marine areas under effective management to improve the status of biodiversity (Convention on Biological Diversity, 2020).

Using this target as a reference, percentage of protected areas or/and percentage of restored ecosystems was (Table. 3) used for scoring method. In the Aichi Biodiversity report, Target 15 aimed for restoration/conservation of 15% of ecosystems/habitats. Target 11 aimed for effective conservation and management of at least 10% of coastal and marine areas.

TABLE 3: CCS SCORING METHODOLOGY FOR BIODIVERSITY RICHNESS.

Bad	0% of degraded ecosystems restored or/and ecosystems/habitats under protection/conservation.
Poor	10% of degraded ecosystems restored or/and ecosystems/habitats under protection/conservation.
Satisfactory	15% of degraded ecosystems restored or/and ecosystems/habitats under protection/conservation.
Good	20% of degraded ecosystems restored or/and ecosystems/habitats under protection/conservation.
Excellent	30% of degraded ecosystems restored or/and ecosystems/habitats under protection/conservation.

2. WFD waterbody status.

Water Framework Directive water quality status (European Commission, 2003). The WFD requires surface water classification through the assessment of ecological status or ecological potential, and surface water chemical status. The directive includes the quality elements that must be used for the assessment of ecological status/potential. The list of quality elements is sub-divided into three groups of 'elements': (1) biological elements, (2) hydromorphological elements supporting the biological elements, and (3) chemical and physio-chemical elements supporting the biological elements. The detailed guidance on the assignment of water bodies to any of the ecological status and ecological potential classes can be viewed in the document 'Guidance document no.13 – Overall approach to the classification of ecological status and ecological potential' (European Commission, 2003). The definition of ecological status looks at the abundance of aquatic flora and fish fauna, the availability of nutrients, and aspects like salinity, temperature and pollution by chemical pollutants (European Commission, 2010). The basic principle of the WFD is that water resources need to fulfil as many environmental functions as possible without sacrificing their longer-term sustainability and accessibility. The development and (inter)calibration of the necessary monitoring and evaluation methos are delegated to the individual member states whose tasks involve the identification of the biological parameters that best describe the ecological status of surface waters. Each parameter

is described by a numerical index expressed as the ratio between the observed ecological quality and a reference condition, defined as the ecological status expected in the absence of human disturbance. The numerical values of all such indices are therefore expressed as Ecological Quality Rations (EQRs). [5]The WFD classification scheme (Fig. A2) for surface water ecological status includes five categories: (1) high status, (2) good status, (3) moderate status, (4) poor status, and (5) bad status. The EQRs range from 0 – 1 and it is translated into CCS scoring method as below (Table. 4); WFD colour grading system (blue, green, yellow, orange, red) was adapted to CCS framework colour system (dark green, green, yellow, orange, red) for global adaptability.

TABLE 4: CCS SCORING METHODOLOGY FOR WATER BODY QUALITY.

Bad	EQR 0 – 0.2
Poor	EQR 0.2 – 0.4
Satisfactory	EQR 0.4 – 0.6
Good	EQR 0.6 – 0.8
Excellent	EQR 0.8 - 1

Global Environmental Change

In this category, global environmental changes include shifts in precipitation pattern, surface temperatures, sea level rise, ocean/sea salinity, etc. In order to evaluate the degree of change in these elements, there has to be a baseline (i.e., reference level). IPCC reports have presented different scenarios and predictions of shifts in global environmental change for the coming years. However, for higher confidence and certainty, localized data was used instead of IPCC scenarios for the credibility of the results.

1. **Sea level rise.**

For the SLR, the historical mean data on sea level rise of 40 cm from 1842 to 2019 has been taken. This is 50% more than expected 27 cm expected for the region. Since this is more than 50% of an expected rise, this indicator was qualitatively measured as ‘bad’.

Low-confidence indicator:

This indicator has no reference data adequate to establish a quantitative scoring system. Thus, it is qualitatively evaluated and is an indicator with low confidence.

[5] The WFD classification scheme for surface water ecological status can be found under the Appendices.

2. Precipitation pattern.

Precipitation patterns were taken from the Roches point station in the system area. The latest year for which the data is available is 2021. The precipitation pattern for the 2021 (Fig.8) is compared with the Long-Term Average (LTR; 1981-2010) to check for the deviation degree. The precipitation pattern for the 2021 does not seem much deviated from the LTR and thus, this sub-category was qualitatively given the status 'satisfactory'.

Low-confidence indicator:

This indicator has no reference data adequate to establish a quantitative scoring system. Thus, it is qualitatively evaluated and is an indicator with low confidence.

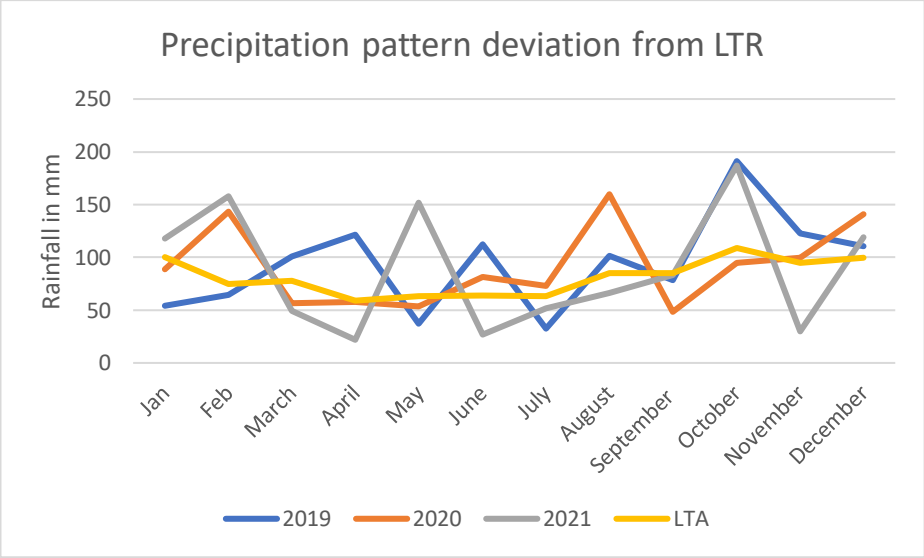

FIGURE 8:2021 PRECIPITATION PATTERN DEVIATION FROM LTR.

3. Temperature change.

Temperature changes were taken from the Roches point station in the system area. The latest year for which the data is available is 2021. The precipitation pattern for the 2021 (fig.9) is compared with the Long-Term Average (LTR; 1981-2010) to check for the deviation degree.

The precipitation pattern for the 2021 does not seem much deviated from the LTR and thus, this sub-category is qualitatively given the status ‘satisfactory’.

Low-confidence indicator: This indicator has no data adequate to establish a quantitative scoring system. Thus, it is qualitatively evaluated and is an indicator with low confidence.

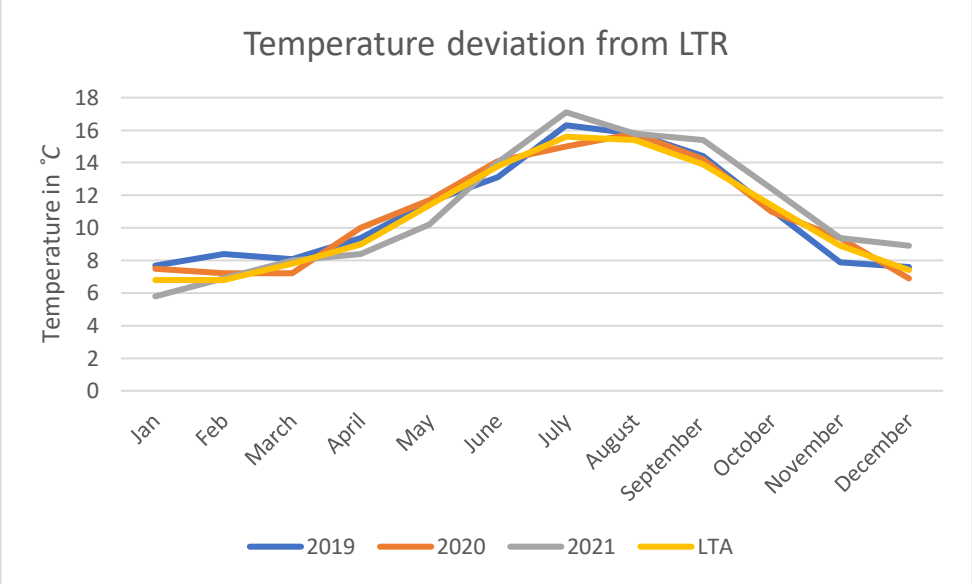

FIGURE 9: 2021 TEMPERATURE DEVIATION FROM THE LTR.

Shifts in Coastal Dynamics

Coastal dynamics include currents, waves, tides and wind speed. One way to determine the state of change of coastal dynamics is to refer to the historical trend of an individual system. For example, the tidal stability over a certain amount of time or referring to historical records. The degree of changes will differ based on different regions/locations.

1. **Tides.**

Tidal stability has been observed and stated over a -177- years period. Thus, this sub-category is qualitatively measured as ‘excellent’.

Low-confidence indicator: This indicator has no reference data adequate to establish a quantitative scoring system. Thus, it is qualitatively evaluated and is an indicator with low confidence.

2. **Sediment cycles.**

Erosion rate. In overall Ireland, the rate of erosion is currently estimated at 0.2-1.6 m per annum; 0.2 m is set as minimum threshold and 1.6 m is set as maximum threshold. Taking the past erosion rate data available specifically for Cork Harbour, this sub-category is qualitatively measured as 'excellent'; erosion data available for Cork Harbour is 0.25-0.3 m per annum.

Biogeochemical and physical flows

CBD's Aichi Biodiversity *Target 8* is to reduce the pollution levels that are not detrimental to ecosystem function and biodiversity. The levels can be flexible based on the system area and the type of ecosystems and biodiversity present (Convention on Biological Diversity, 2020).

Using this target as a reference, scoring system – i.e., the safe pollution levels that are considered not detrimental to individual system's function can vary. The threshold values are taken from the report by EPA "Water Quality in 2020: An Indicators Report" (Trodd, et al., 2021).

1. **Nitrogen.**

Nitrogen levels in coastal waters is measured to determine the pollution levels. High nitrogen levels in coastal ecosystem encourages the growth of algae and aquatic plants; increased algal growth can limit the oxygen levels as well as shading of sunlight needed by other aquatic plants. The scoring method below (Table. 5) was established for determining the status of Cork Harbour coastal water bodies.

2. **Phosphorus.**

Phosphate is another limiting nutrient in waters that can affect the growth of algae and aquatic plants. If phosphate is present in higher concentrations, it can cause eutrophication. The scoring method below (Table. 5) was established for determining the phosphorus status of Cork Harbour coastal water bodies.

TABLE 5: CCS SCORING METHODOLOGY FOR NITROGEN AND PHOSPHORUS VALUES IN COASTAL WATERS.

Bad	>50% above threshold value
Poor	1% to 50% above threshold value
Satisfactory	-14% to 0% above threshold value
Good	- 49% to -15% above threshold value
Excellent	<-50% above threshold value

4.2.2 Social and Culture

Societal benefits

1. **Goods and Services.**

Another indicator for measuring goods and services provided by Ireland's blue economy sector is the overall aquaculture value of Cork County in 2015. The lowest and the highest value of overall aquaculture value of counties in Ireland at the time of data collected was used as a reference to establish the scoring method (Table. 6) for this indicator. The lowest and the highest aquaculture values are €0.8 m and €42.0 m respectively (Norton, et al., 2018).

TABLE 6: CCS SCORING METHODOLOGY FOR COASTAL GOODS AND SERVICES.

Bad	overall aquaculture value of €0 m – € 10 m
Poor	overall aquaculture value of € 10 m – € 20 m
Satisfactory	overall aquaculture value of € 20 m – € 30 m
Good	overall aquaculture value of € 30 m – € 40 m
Excellent	overall aquaculture value of € 40 m – € 50 m

Demographics

1. **Education.**

The expected benefits of education go beyond earnings and employment, by affecting health and longevity, happiness and pro-environmental behaviour (Yann, et al., 2021). Education is critical in helping populations understand and address the impacts of climate change, and in encouraging the changes in attitudes and behaviours needed to help them address the cause of climate change, adopt more sustainable lifestyles and develop skills that support modules of economies, as well as to adapt to the impact of climate change.

Using Ireland's trend and performance on SDG 4 as a reference point, the following scoring method was established (Table. 7). The country is in increasing trend and SDG 4, indicator "Lower Secondary Completion rate" was used as a reference point. In the country's profile,

this indicator has reached a 100% value meaning there's a 100% lower secondary completion rate.

TABLE 7: CCS SCORING METHODOLOGY FOR EDUCATION STATUS.

Bad	0% - 20% lower secondary completion rate
Poor	20% - 40% lower secondary completion rate
Satisfactory	40% - 60% lower secondary completion rate
Good	60% - 80% lower secondary completion rate
Excellent	80% - 100% lower secondary completion rate

2. **Social class.**

The regions are divided to nine regions in which the study area falls into South-West region. The number of homeless people in South-West region is 8.3% of the total in the region. Using all Ireland as a reference, the highest percentage (in Dublin region) was set as the upper threshold and the lowest percentage (North-West region) was set as the lower threshold (Table. 8). The highest percentage is 70.1% in Dublin and the lowest is 0.8% in North-West region (CSO statistical publication, 2020).

TABLE 8: CCS SCORING METHODOLOGY FOR SOCIAL CLASS.

Bad	60% - 75% of Homeless Persons in 2019
Poor	45% - 60% of Homeless Persons in 2019
Satisfactory	30% - 45% of Homeless Persons in 2019
Good	15% - 30% of Homeless Persons in 2019
Excellent	0% - 15% of Homeless Persons in 2019

Social wellbeing

1. **Bathing beaches.**

Two bathing beaches that are present in the system area are both qualified to have 'excellent' water quality. The quality control and bathing water standards are based on the EU directive of Bathing Water Directive 2006/7/EC. The water qualities are divided into four categories according to their level of quality: poor, sufficient, good, and excellent. These levels are categorized by numerical quality standards for bacteriological quality (Intestinal enterococci and Escherichia coli) (European Commission, n.d.). Table below (Table. 9) is the scoring method for CCS framework.

Low – confidence scoring method:

This indicator has an established scoring system under the EU Bathing Water Quality Directive. This four categorical scoring system is directly translated to CCS five categorical scoring system resulting in one missing category (i.e., 'bad').

TABLE 9: CCS SCORING METHODOLOGY FOR BEATHING BEACH QUALITY.

Bad	-
Poor	Poor – the water quality has not met the minimum standard
Satisfactory	Sufficient – the water quality meets the minimum standard
Good	Good – generally good water quality
Excellent	Excellent – the highest, cleanest class

2. Water quality

Public water supply quality was taken from the 10 stations in the system area (Table. A5). The mean data and all the parameters that define the water quality supply are all within threshold values and defined as having 'excellent' quality for the category (European Union, 2014).

3. Health.

Health status by county is taken as an indicator to measure the health status of the system area. The data for the indicator as well as the reference values were taken from the Census of Population 2016 – Profile 9 Health, Disability and Careers (CSO statistical publication, 2017). The highest percentage of population with good health status is 89.9% in Dun Laoghaire-Rathdown and the lowest percentage with Dublin at 82.8% of population with good health status. The Irish Government has already established a scoring system with three categories – good or very good (87%), fair (8%), bad or very bad (1.6%). Using these as a reference, the following scoring method (Table. 10) was translated into CCS methodology.

TABLE 10: CCS SCORING METHODOLOGY FOR POPULATION HEALTH STATUS.

Bad	0% - 5% of population with good health status in 2016
Poor	5% - 10% of population with good health status in 2016
Satisfactory	10% - 80% of population with good health status in 2016
Good	80% - 85% of population with good health status in 2016
Excellent	85% - 90% of population with good health status in 2016

Identity

1. Sense of place.

The number of sites of heritage importance is used as in indicator here and this sub-category was qualitatively scored. With rich historical heritage and cultural heritage closely linked to the harbour and coastal area, this category was given the score good.

Low-confidence indicator:

This indicator has no reference data adequate to establish a quantitative scoring system. Thus, it is qualitatively evaluated and is an indicator with low confidence.

Social resilience

1. **Vulnerability.**

Physical strength and the life experience differ in different age groups. The average age population in rural area of Cork County is 38.4 while the average age population in urban area of Cork County is 35.8. Taking the factors of aging and resilience into account, this sub-category was measured as 'satisfactory'.

4.2.3 Economics

Security

1. **Livelihoods.**

2018 GVA was divided over 7 years average GVA (2010-2017) to measure the growth of GVA by ocean economy of different sectors (Table. A2). The rate was scored as below (Table. 11):

Low-confidence scoring method:

This indicator looks at the deviation of the latest available GVA from the 7 years average GVA (2010-2017). This might not be the best fit way to score this type of indicator and thus, makes it an indicator with low confidence.

TABLE 11: CCS SCORING METHODOLOGY FOR OCEAN ECONOMY THROUGH THE GROWTH OF GVA.

Bad	< 0.1
Poor	0.1 – < 0.5
Satisfactory	0.5
Good	0.5 – 0.9
Excellent	> 0.9

2. **Gender.**

The ideal percentage of equally distributed gender in high-ranking positions in employment sector is 50%-50% between female and male. Thus, the scoring method below (Table. 12) was produced to measure the status of gender equality.

TABLE 12: CCS SCORING METHODOLOGY FOR GENDER EQUALITY IN EMPLOYMENT.

Bad	0% - 10% of proportions of managers, directors and senior officials who are female in South-West region in 2017.
Poor	10% - 20% of proportions of managers, directors and senior officials who are female in South-West region in 2017.

Satisfactory	20% - 30% of proportions of managers, directors and senior officials who are female in South-West region in 2017.
Good	30% - 40% of proportions of managers, directors and senior officials who are female in South-West region in 2017.
Excellent	40% - 50% of proportions of managers, directors and senior officials who are female in South-West region in 2017.

3. Employment patterns.

Employment pattern is another indicator to measure the economics security of the system. The document 'Cork County Development Plan Review – Economy and Employment' (Cork County Council, 2019).

Low-confidence indicator:

This indicator has no reference data adequate to establish a quantitative scoring system. Thus, it is qualitatively evaluated and is an indicator with low confidence.

Infrastructure

1. Energy supply.

The proportion of households with oil central heating was used as an indicator to measure the population with access to energy supply. For this indicator, Irish Government has already established a scoring category in the statistics database of Central Statistics Office (Central Statistics Office, 2019). This scoring method was translated to CCS methodology (Table. 13) to score the energy status of Cork County.

TABLE 13: CCS SCORING METHODOLOGY FOR ENERGY SUPPLY.

Bad	< 20% of households with oil central heating in 2016
Poor	20% - 46% of households with oil central heating in 2016
Satisfactory	46% - 55% of households with oil central heating in 2016
Good	55% - 61% of households with oil central heating in 2016
Excellent	> 61% of households with oil central heating in 2016

2. Transport.

Transportation methods to work was used as an indicator to measure the transport infrastructure. The data was taken from the Cork County Development Plan Review: Economy

and Employment Background document No. 6 (Cork County Council, 2020). Five categories of transport modes were extracted from the document: (1) on foot, bicycle, bus, train; (2) driving cars; (3) motorcycle; (4) passenger in car; (5) work vehicles; the document lists on foot, bicycle, bus, and train as sustainable transport modes. The scores were given to the transport modes (Table. A6) according to the carbon footprint of travel per kilometre; the study was published by the UK government Department for Business, Energy & Industrial Strategy. Summarised and simplified data was taken from Our World in Data (Our World in Data, 2020). The scoring method below was then later produced for CCS framework (Table. 14).

TABLE 14: CCS SCORING METHODOLOGY FOR TRANSPORT INFRASTRUCTURE.

Bad	score of 1
Poor	score of 2
Satisfactory	score of 3
Good	score of 4
Excellent	score of 5

3. Access.

Population by frequency of services offered by nearest public transport stop was an indicator used to measure the ease of access to public transport. Cork County has 47% of population that has <10 frequency of services, 43.9% of population that has 10 - <50 frequency of services, and 9.2% of population that has more than 50 frequency of services. This sub-category was qualitatively measured as having a 'satisfactory' status due to almost half of the population in the county only having less than 10 frequencies of services. This indicates that in times of emergency needs, half of the population has less than 10 frequencies of services to commute.

Low-confidence indicator:

This indicator has no reference data adequate to establish a quantitative scoring system. Thus, it is qualitatively evaluated and is an indicator with low confidence. This is a low-confidence indicator due to it being a proxy data taken from the whole of Ireland (or country level).

4. Tourism.

Travel and Tourism Competitiveness index was an indicator to measure the performance of tourism sector. This indicator is a proxy indicator that represents the tourism performance of Ireland as a country. The index ranges from 1-7 and translating this into CCS five categorical scores, scoring method below was produced (Table. 15).

Low-confidence indicator:

This is a low-confidence indicator due to it being a proxy data taken from the whole of Ireland (or country level) and due to this, there is an uncertainty in translating scores from one methodology to another.

TABLE 15: CCS SCORING SYSTEM FOR TRAVEL AND TOURISM INDEX.

Bad	0 – 1.4
Poor	1.5 – 2.8
Satisfactory	2.8 – 4.2
Good	4.3 – 5.6
Excellent	5.7 – 7.0

Economic wellbeing

1. **Equality.**

GINI index was used to measure the equality. The scoring method was established (Table. 16) through data taken from the World Bank database of GINI indices of all countries from 1960 to 2021, Poverty and Inequality platform (World Bank, 2018). The lowest GINI index of all time was used as a lower boundary threshold and the highest GINI index of all time was used a higher boundary threshold. The lowest GINI index was achieved by Czech Republic in 1992 (Index of 20.7) and the highest GINI index was achieved by Malawi in 1997 (index of 65.8) (World Bank, 2018). The highest value in the scoring system was set to 65.7 instead of 65.8 due to the awkwardness in segregating scores between categories.

TABLE 16: CCS SCORING METHODOLOGY FOR GINI INDEX.

Bad	> 65.7 of GINI index
Poor	50.7 – 65.7 of GINI index
Satisfactory	35.7 – 50.7 of GINI index
Good	20.7 – 35.7 of GINI index
Excellent	< 20.7 of GINI index

2. **Income.**

Consistent poverty rate was used as an indicator to measure the income/household prosperity. The data was taken from the Ireland's UN SDG progress report published by the Central

Statistics Office (Central Statistics Office, 2018). The Irish Government has their own scoring method to rate the status of poverty rates in different regions and this was translated into CCS methodology (Table. 17).

TABLE 17: CCS SCORING METHODOLOGY FOR INCOME STATUS.

Bad	< 3.5 consistent poverty rate by region in 2018
Poor	3.5 – 5.3 consistent poverty rate by region in 2018
Satisfactory	5.3 – 6.3 consistent poverty rate by region in 2018
Good	6.3 – 7.3 consistent poverty rate by region in 2018
Excellent	> 7.3 consistent poverty rate by region in 2018

Industry

1. **Renewable energy.**

The share of renewable energy contributed by the system area is one of the indicators to measure the industry's energy structure. The Sustainable Energy and Authority of Ireland has published a data on energy flow for electricity generation where percentages of electricity produced by various sources and total fuel inputs needed for electricity generation (Sustainable Energy Authority of Ireland, 2020). Ireland wind energy contributes to 21.9% of electricity from the wind energy. Crocane Wind Farm and Cork Lower Harbour Energy Group's Wind developments in Ringaskiddy represents over 17% of Ireland's installed wind power. In overall Ireland, wind power contributes to 21.9% of the electricity and this was used as a reference to produce the scoring method below (Table. 18).

TABLE 18: CCS SCORING METHODOLOGY FOR RENEWABLE ENERGY CONTRIBUTION.

Bad	0% - 4.4% of wind energy contribution
Poor	4.4% - 8.8% of wind energy contribution
Satisfactory	8.8% - 13.2% of wind energy contribution
Good	13.2% - 17.6% of wind energy contribution
Excellent	17.6% - 22% of wind energy contribution

2. **Extractive.**

The indicator to measure the societal benefits is the goods and services provided by Ireland's blue economy sector. The data was extracted from the report "Valuing Ireland's Blue Ecosystem Services" (Norton, et al., 2018). Using the highest and the lowest offshore capture

fisheries value, the following ranks/categories were established for the scoring method (Table. 19). The highest value of offshore capture fisheries value in Ireland per ICES rectangle is €20 m - €30 m; the lowest is €0.0 m - €0.1 m.

TABLE 19: CCS SCORING METHODOLOGY FOR COASTAL EXTRACTIVE RESOURCES.

Bad	offshore capture fisheries value of €0.0 m - €0.1 m
Poor	offshore capture fisheries value of €0.1 m – €1.0 m
Satisfactory	offshore capture fisheries value of €1.0 m – €5.0 m
Good	offshore capture fisheries value of €5.0 m – €20 m
Excellent	offshore capture fisheries value of €20 m – € 30 m

Dependency

1. **Resources.**

The dependency is measured by using percentage of jobs by sectors as an indicator. The percentage of dependency on the coastal related jobs is used to score this sub-category. Looking at the resilience of the system in relations to climate change extreme events, to SLR, the lower the number of dependent jobs on coastal resources is deemed as the lower the economic impacts received by the system when such coastal extreme events occur. On the other hand, the lower percentage of ocean or coastal-related jobs in the system area projects the idea that the livelihood of the population is not entirely dependent on the coastal resources; this assumption instead was used to measure *economic dependency* on coastal resources. Looking at percentage breakdown of jobs by industrial groups in Cork County, the number of jobs *assumed* to be related to coastal jobs are of 8% (agriculture, forestry, and fishing) (Table. A3). However, this data is a proxy data extracted from the county level, the indicator was indicated as a low-confidence indicator.

Low-confidence indicator:

This indicator has no reference data adequate to establish a quantitative scoring system. Thus, it is qualitatively evaluated and is an indicator with low confidence.

4.2.4 Governance and Policy

Organisations

1. **Civils and NGOs.**

The Irish Environmental Network is made up of environmental organisations in Ireland. The variety of environmentally oriented organisations in the country was taken as a qualitative measure to score this sub-category.

Low-confidence indicator: This indicator has no reference data adequate to establish a quantitative scoring system. Thus, it is qualitatively evaluated and is an indicator with low confidence.

Law and Justice

1. **Legislations.**

As for the legislation, number of protected areas that are ecologically important. In Cork Harbour system area, there is a RAMSAR site, an SAC and an SPA site designated. These sites are important ecologically and some of the species are of international importance. These species and ecosystems are in protection as they are required under Natura 2000. Thus, this sub-category was given an 'excellent' status.

Low-confidence indicator: This indicator has no reference data adequate to establish a quantitative scoring system. Thus, it is qualitatively evaluated and is an indicator with low confidence.

2. **Enforcement.**

Cork County Council has an environmental division which oversees different environmental services (Cork County Council, n.d.). The county council administers coastal related environmental services for air quality, energy & climate change, environmental awareness, food safety, litter and illegal dumping, waste and recycling, and water quality. These services are all in place and established to meet the challenges the country is facing or goals the country is lacking behind to meet (based on OECD Environmental Performance of Ireland). Existence of such services in the county gives this sub-category good status. Excellent status was not given due to the uncertainty of the competency and reliability or functionality of the services; there are still more progresses that are needed to meet the environmental objectives. There are number of climate-change adaptation strategies in place: Cork County Climate Change

Adaptation Strategy and Cork City Climate Change Adaptation Strategy. Enforcement and compliance promotion are well co-ordinated, but non-compliance levels are relatively high. Thus, this sub-category was given the status of satisfactory.

Low-confidence indicator:
This indicator has no reference data adequate to establish a quantitative scoring system. Thus, it is qualitatively evaluated and is an indicator with low confidence.

Representation and Power

1. **Gender.**

As for the representation and power, gender equality in terms of percentage of seats in local government held by women in South-West region in 2019 was used as an indicator. The ideal gender representation would be 50% for each gender and using this, the scoring method was produced (Table. 20). In the South-West region the percentage is 22.7% which falls in the category of satisfactory.

TABLE 20: CCS SCORING METHODOLOGY FOR GENDER REPRESENTATION AND POWER.

Bad	0% - 10% of seats held by women in South-West region in 2019
Poor	10% - 20% of seats held by women in South-West region in 2019
Satisfactory	20% - 30% of seats held by women in South-West region in 2019
Good	30% - 40% of seats held by women in South-West region in 2019
Excellent	40% - 50% of seats held by women in South-West region in 2019

Legitimacy and Accountability

1. **Voice and accountability.**

Ireland ranked 95.169 percentile rank in 2020 in this indicator giving it an excellent status for this sub-category as per the scoring method produced (Table. 21). Public participation is a central element of policy, licensing, and planning decision in Irish government.

Low-confidence indicator:
This is a low-confidence indicator due to it being a proxy data taken from the whole of Ireland (or country level).

TABLE 21: CCS SCORING METHODOLOGY FOR VOICE AND ACCOUNTABILITY.

Bad	0 - 20 percentile rank
Poor	21 – 40 percentile rank
Satisfactory	41 – 60 percentile rank
Good	61 – 80 percentile rank
Excellent	81 – 100 percentile rank

2. Control of corruption.

Using the same scoring method (Table. 22), Ireland received an excellent status due to its 91.346 percentile rank in this indicator.

Low-confidence indicator:

This is a low-confidence indicator due to it being a proxy data taken from the whole of Ireland (or country level).

TABLE 22: CCS SCORING METHODOLOGY FOR CONTROL OF CORRUPTION.

Bad	0 - 20 percentile rank
Poor	21 – 40 percentile rank
Satisfactory	41 – 60 percentile rank
Good	61 – 80 percentile rank
Excellent	81 – 100 percentile rank

Resource management

1. Management

Aichi Biodiversity *Target 2* – integrating biodiversity values into national and local development or poverty reduction strategies, as well as into national accounting and reporting systems (Convention on Biological Diversity, 2020).

Aichi Biodiversity *Target 6* – marine biodiversity is managed sustainably (i.e., fish stocks and aquatic plants), plans and measurements to recover depleted marine stocks, and marine species and ecosystems are within safe limits.

Aquaculture management and the existence of acts and regulations are used as an indicator to measure the coastal resources management in this category. For aquaculture and foreshore

management, there are several acts, regulations and licenses established. The main management is governed by Fisheries Acts which have been amended and to Fisheries and Forshore Act. There are also Martime Safety Act, Foyle and Carlingford Act, Foreshore and Dumping at Sea Act, Sea Fisheries Act and Marine Institute Act. The licenses required under these acts for fishing are Marine FInFish license, Land-based FinFish license, and Shellfish license (Department of Agriculture, Food and the Marine, 2022). Environmental licensing has become more efficient but extending general binding rules would help reduce the administrative burden on low-impact installations. Thus, this category was given 'good' status.

Low-confidence indicator:

This indicator has no reference data adequate to establish a quantitative scoring system. Thus, it is qualitatively evaluated and is an indicator with low confidence.

Final score calculation

The averaging of the values was done using an arithmetic mean method. The scores each dimension were calculated by totalling the scores of categories present (i.e., five) and divided by the total number of categories. The final scoring of an overall system also was calculated using the same formula. Arithmetic mean is used for calculating average due to the values of the indicators being independent of each other. However, this method of calculating produces uncertainties when outliers are involved.

$$A = \frac{1}{n}\sum_{i=1}^{n} a_i$$

A = arithmetic mean

n = number of values

a_i = data set values

[Chapter 5 – Results and Discussion]

This section discusses the results and gives commentary on the weaknesses and strengths of the methodologies and the confidence of the results produced, and suggestions on what could be improved for future studies.

5.1 Sub-categories and Indicators

5.1.1 Environment and Ecology

TABLE 23: ENVIRONMENT AND ECOLOGY DIMENSION INDICATORS BREAKDOWN.

Category	Sub-category	Indicators	Score	Final Score
1. Alterations of Landscape	Landcover change	Corine landcover data set 2012-2018	Satisfactory	Good
	Sea and land change	Land reclamation and land development after 1934-2005.	Excellent	
2. Ecosystem Functions	Biodiversity richness	SPAs species diversity	Excellent	Excellent
		SAC species diversity	Excellent	
	WFD waterbody status	Coastal waterbody WFD status – latest cycle	Good	
		River waterbody WFD status – latest cycle	Satisfactory	
		Transitional waterbody WFD status – latest cycle	Satisfactory	
		Ground waterbody WFD status – latest cycle	Good	
3. Global Environmental change	Sea level rise	Historical data on sea level rise from 1842 to 2019	Bad	Poor
	Precipitation pattern	Total rainfall in mm collected at Roches Point (2019-2021)	Satisfactory	
	Temperature change	Mean temperature in Celsius collected at Roches Point (2019-2021)	Satisfactory	
4. Shifts in coastal dynamics	Tides	Tidal range/ tidal stability	Excellent	Excellent
	Sediment cycles	Erosion rates for: East of Cork Harbour (1970's and 2006 data)	Excellent	

		West of Cork Harbour (1970's and 2000 data)		
5. Biogeochemical and physical flows	Nitrogen	Estuarine and Coastal Water Winter Dissolved Inorganic Nitrogen 2018-2020	Poor	Satisfactory
	Phosphorous	Estuarine and Coastal Water Winter Molybdate Reactive Phosphorus 2018-2020	Satisfactory	

[Results]

Alteration of landscape is not very apparent giving it a 'good' status (table.23 & fig.10). Landcover change is 'satisfactory' while sea and land change is 'excellent'. The ecosystem functions are thoroughly preserved with 'excellent' biodiversity richness and 'good' to 'satisfactory' quality in waterbodies. Global environmental changes are 'poor' with SLR having the most significant change (i.e., 'bad' status), followed by 'satisfactory' changes in precipitation pattern and temperature. Shifts in coastal dynamics is 'excellent' with tidal stability and low erosion rates. Biogeochemical flows into the waterbodies of the harbour are in 'satisfactory' status; dissolved inorganic nitrogen values are high giving it a 'poor' status, while reactive phosphorous levels are at a 'satisfactory' level. This gives the overall status of environment and ecology dimension as 'good' (table.23).

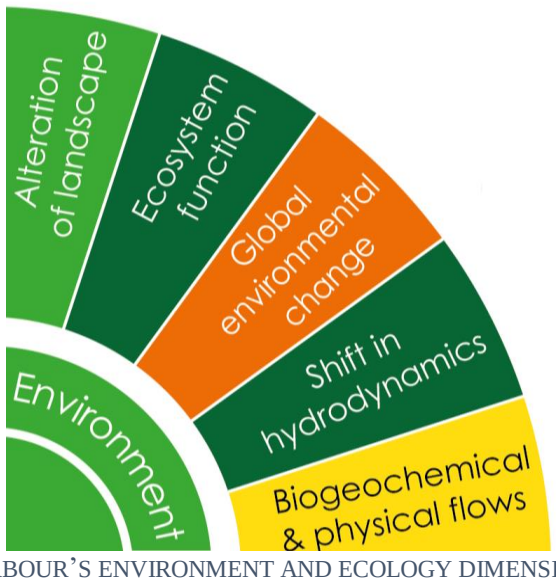

FIGURE 10: CORK HARBOUR'S ENVIRONMENT AND ECOLOGY DIMENSION IS IN 'GOOD' STATUS.

[Discussion]

Environment and ecology dimension overall attained a ‘good’ status despite a ‘poor’ status and a ‘satisfactory’ status in global environmental change category and biogeochemical & physical flows category, respectively.

Alteration of landscape attained a ‘good’ status; this category was evaluated based on Aichi Biodiversity Target 5 (Convention on Biological Diversity, 2020). Based on this evaluation method, the land-cover change is in ‘satisfactory’ status. The way this indicator was evaluated was in a qualitative manner where subjective conclusion was drawn; the conclusion was “not many natural areas have changed between 2012 and 2018, but the cultivation lands have increased sparsely”. The principal argument for the qualitative methodology is the lack of access to GIS data Irish Corine Landcover change dataset. With the availability of this dataset, quantitative analysis is possible, and the confidence of the indicator will be higher. Land reclamation is another indicator used to evaluate the alteration of landscape in the system area. The dataset is a historical dataset that was taken from the years 1934 to 1995 and the years 1995 to 2005. This produced another uncertainty; the land change might have produced a different rate with the possibilities of new regulations and acts being placed.

Ecosystem function was a category evaluated using existence of protected areas and WFD waterbody quality status. The existence of protected areas, such as SPAs, SACs and RAMSAR sites, attained an ‘excellent’ status, referring to the scoring methodology of 30% of the ecosystems/habitats under pressure. However, it is important to note that the system area itself is not extensive and the harbour estuary itself is a very important habitat for migratory bird species. This has led to this indicator achieving an ‘excellent’ status. Bathing water quality is not an indicator in this sub-category but rather WFD water quality parameters were used; this resulted in two water bodies (i.e., coastal waterbody and ground waterbody) with ‘good’ status, and two water bodies (i.e., river waterbody and transitional waterbody) with ‘satisfactory’ status. River waterbodies in the system area was evaluated as having ‘satisfactory’ status; this is an averaged status for all river waterbodies present in the area. The rivers that are adjacent to settlement areas gave ‘satisfactory’ or ‘poor’ statuses. The plausible causes for this quality are presence of sewage treatments plants (plants that treat sewage with more than >500 people), river catchments (runoffs from settlements), agriculture pressures, and urban runoff pressures (Environmental Protection Agency, 2022). Transitional waterbody in the system area was evaluated as having ‘satisfactory’ status; these waterbodies are in the vicinity of river mouths are partly saline but are also influenced by freshwater flows from adjacent waters (INSPIRE, n.d.). The plausible causes for this quality are the adjacent

settlements (Cork City and Middleton), wastewater discharges, discharges from storm water overflows, presence of sewage treatments plants (plants that treat sewage with more than >500 people), presence of waste emission sites (landfills, hazardous waste disposal, and transfer stations), urban runoff pressures, and anthropogenic pressures (nutrient, organic, and sediment pollutions) (Environmental Protection Agency, 2022).

Global environmental change category attained a 'poor' status, but this is an expected outcome due to global warming and climate changes in play (Pörtner et al., 2022). The indicators used in this category are the indicators that are associated with global warming and climate change. Localised dataset with data from the past years was used; however, all the indicators are stated as low-confidence indicators due to the inadequate data available to establish a quantitative scoring system.

Shifts in hydrodynamics attained an 'excellent' status; tidal stability was observed, and the erosion rate was insignificant. This is due to Cork Harbour being a naturally sheltered bay system (ref) and the system not receiving many impacts from the hydrodynamic elements compared to the other exposed coastal areas (National Geographic Society, n.d.).

Biogeochemical and physical flows attained a 'satisfactory' status. Nutrient loading from industrial and domestic outfalls discharge (Nash, et al., 2005). The sources for nitrogen and phosphorous loadings include urban wastewater (sewage) discharge, waste facilities, urban areas that failed to comply with one or more of the EU sewage treatment standards, adjacent rivers with urban run-off pressures, and rivers with agriculture pressures that flow into the harbour (Environmental Protection Agency, 2022).

5.1.2 Social and Culture

TABLE 24: SOCIAL AND CULTURE DIMENSION INDICATORS BREAKDOWN.

Category	Sub-category	Indicators	Score	Final Score
1. Societal Benefits	Goods and services	Aquaculture value of Cork County (2015)	Good	Good
2. Demographics	Education	Retention rates of secondary schools	Excellent	Excellent
	Social Class	Percentage of homeless persons 2019	Excellent	
3. Social well-being	Amenity value	Bathing beach quality	Excellent	Excellent
	Water quality	Public water supply quality (2016)	Excellent	
	Health	Health status in Cork County (2016)	Excellent	

4. Identity	Sense of place	Sites of heritage importance	Good	Good
5. Social resilience	Vulnerability	Average age of population by county (Census 2016)	Satisfactory	Satisfactory

[Results]

Societal benefits provided from the aquaculture is 'good' (table. 24 & fig. 11), the demographic structures are in 'excellent' statuses, and social well-beings provided by is also in 'excellent' status. Identity, as a sense of place, is in 'good' status with a great number of sites with heritage importance. Social resilience as an age vulnerability is in 'satisfactory' status. This gives the overall status of social and culture dimension as 'good' (table. 24). European Commission produced a report that highlights the important benefits that investment in education can bring to the economy and society, and proves that investing in education sector will contribute to boosting social and economic resilience in Europe (Algan, et al., 2021).

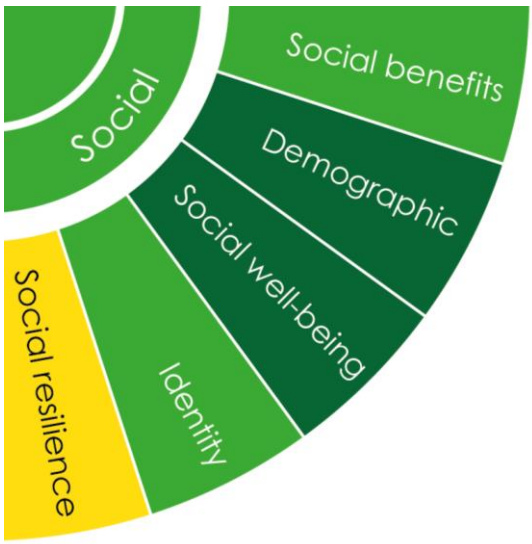

FIGURE 11: CORK HARBOUR'S SOCIAL AND CULTURE DIMENSION IS IN 'GOOD' STATUS.

[Discussion]

OECD termed societal benefits as 'current transfers received by households intended to provide for the needs that arise from certain events or circumstances; for example, sickness, unemployment, retirement, housing, education or family circumstances (OECD, 2001). Climate Justice is a term that examines the concepts like just division, fair sharing, and equitable distribution of the benefits and burdens of climate change and responsibilities to deal with the consequences. The impacts of climate change are not borne equally or fairly; between rich and poor, women and men, and older and younger generations (Simmons, 2020). It is

important to recognize that different key groups are affected differently by climate change; factors defining these key groups include income groups, age groups, people with disabilities and gender.

Social and culture dimension overall attained a 'good' status despite a 'satisfactory' status in social resilience. The three indicators are specific to the system area are bathing beaches quality, public water supply quality and the sites of heritage importance; the rest of the indicators for this category were taken from the county level. Thus, the confidence of this dimension status is low. Not only most indicators are proxy indicators, the scoring methods for the indicators are also mostly qualitative; very vague and low-confidence method for one indicator – social resilience. The meaning of social resilience or social vulnerability is very subjective like the meaning of sustainability, and this sub-category was scored subjectively to the author's own interpretation of vulnerability due to conflicting opinions in the literatures.

Societal benefits category attained a 'good' status. The benefits were evaluated in terms of goods and services provided by the system is aquaculture value of Cork County. (Norton, et al., 2018). This is a proxy data extracted from county level but also only represents one employment sector (i.e., aquaculture value). Cork Harbour is a system with many other provisions of ecosystem services; regulatory services from protected areas, cultural services from heritage sites and supporting services from hydrodynamic circulations (Norton, et al., 2018). These factors were not considered or utilised as indicators due to the difficulty in translating ecosystem services into monetary terms. This is a point that can be improved for future studies of such framework as CCS.

Demographics category attained an 'excellent' status; the category, again, can be referred to as low-confidence category due to the data being taken from county level and regional level[6]. The indicators are education as an awareness to climate change and homelessness as a social class status in the system area. Although the category scored an 'excellent' status, with more precise data, there is a possibility of the status shifting to 'good' status.

Social well-being category attained an 'excellent' status; there are two indicators (i.e., bathing beach quality and public water supply quality) that are specific to the system area, but health status of the population is an indicator taken from county level; this puts bias to the result. Compared to other categories, social well-being category is of higher confidence due to

[6] Regional level refers to NUTS geocoded sub-divisions. These regions are divided for statistical purposes and the standard is developed and regulated by the EU. Cork Harbour, under Cork County, belongs to the South-West NUTS region.

the two indicators being specific to the system. However, amenity values might not be the best fit indicator to measure social well-being due to the subjective values and definitions places on these terms (Parliamentary Commissioner for the Environment, 1996).

Sense of place as an identity was evaluated using the sites of heritage importance in the system area. The category attained a 'good' status; this indicator is specific to the site but has a low confidence due to the subjective interpretation of the term 'identity' (Foote & Azaryahu, 2009) and the qualitative scoring methodology.

Social resilience category attained a 'satisfactory' status. This is the category that is with the lowest confidence as it is subjectively evaluated due to the conflicting opinions in the literatures. In terms of physical strength, the younger age groups would surpass the older age groups thus they can be assumed to be more physically capable against weather extreme events in cases of emergency. However, resilience does not decline with age. A study by Cohen et al. in Israel showed that there is a significant rise in community resiliency score in the age groups of 61-75 years as compared with younger age groups (Cohen, et al., 2016). Aging adults have protective factors such as self-esteem, purpose, hope, and self-acceptance – the factors that are associated with resilience in the face of challenges (Burcham, 2021).

Social resilience against climate change should acknowledge different experiences/levels of risks or socio-economic limits to resilience as risks are experienced unequally by people of different socio-economic status (Forsyth, 2018).

5.1.3 Economics

TABLE 25: ECONOMICS DIMENSION INDICATORS BREAKDOWN.

Category	Sub-category	Indicators	Score	Final Score
1. Security	Livelihoods	Direct GVA from Ireland's ocean economy	Excellent	Good
	Gender	Proportions of managers, directors and senior officials who are female in South-West region in 2017	Good	
	Employment patterns	Distribution of jobs (job density) in Cork Harbour region compared to the rest of the county	Good	
2. Infrastructure	Energy supply	Percentage of population with oil	Satisfactory	Satisfactory

		central heating in Cork County (2016)		
	Transport	Means of travel to work (2016)	Bad	
	Access	Population by frequency of services offered by nearest public transport stop	Satisfactory	
	Tourism	Travel & Tourism Competitiveness Index	Good	
3. Economic well-being	Equality	GINI index (2018)	Good	Good
	Income	Consistent poverty rate in South-West region in 2018	Satisfactory	
4. Industry	Renewable energy	Ireland's Energy Hub energy supply; Crocane Wind Farm and Cork Lower Harbour Energy Group's Wind developments in Ringaskiddy	Good	Good
	Extractive resources	Offshore capture fisheries value	Satisfactory	
5. Dependency	Resources	Percentage breakdown of jobs by industrial group	Satisfactory	Satisfactory

[Results]

Economic security is ‘good’ with an ‘excellent’ status in livelihoods directly impacted from ocean economy, and ‘good’ statuses in gender and employment patterns. The infrastructure resilience of the economics dimension is ‘satisfactory’ with transport infrastructure (in terms of carbon footprints) particularly in ‘bad’ status; tourism industry is in ‘good’ status while both energy supply and ease of access are in ‘satisfactory’ statuses. Economic well-being is in ‘good’ status with a GINI index at ‘good’ status and income status at ‘satisfactory’. Renewable energy industry is in ‘good’ status and extractive resources in terms of offshore capture fisheries value is in ‘satisfactory’ status. The dependency on the coastal resources is in ‘satisfactory’ status. This gives the overall status of economics dimension as ‘good’ (table. 25 & fig. 12).

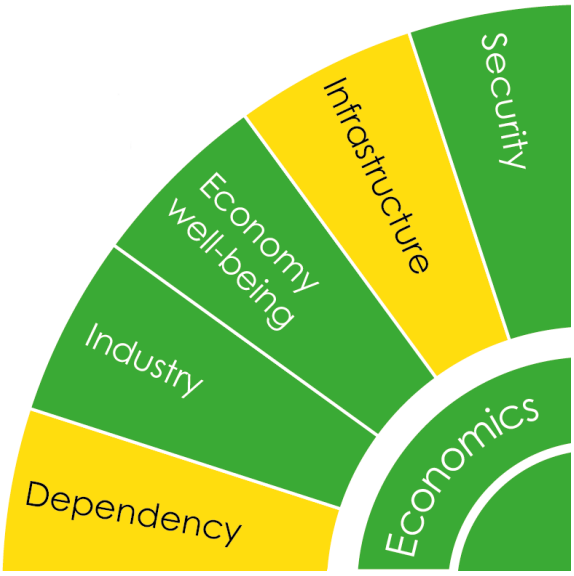

FIGURE 12: CORK HARBOUR'S ECONOMICS DIMENSION IS IN 'GOOD' STATUS.

[Discussion]

Economics dimension attained a 'good' status; two categories with 'satisfactory' statuses and three categories with 'good' statuses. There are two indicators that are specific to the system area but the rest of the indicators are proxy indicators with the data extracted from county level or regional level.

Security (economic security) category attained a 'good' status. Direct GVA was an indicator for the livelihood support from the ocean economy; the indicator is a proxy indicator, and that the data was extracted from the whole of Ireland (i.e., country level) which poorly reflects the harbour's ocean economy. Cork Harbour Economy is an initiative (and termed a community), by Cork County Council, focusing on Cork Harbour as an economic and cultural powerhouse of the South of Ireland (EchoLive, 2021). A webinar took place in 2021 which provided an insight into the growth opportunity of the Cork Harbour Economy. The event stated the Cork Harbour Economy as a driver for the entire Cork region and set growth targets for the year 2040. With this initiative, more precise data in terms of economics inputs from the Cork Harbour Economy to Ireland as a country or Cork as a county can be efficiently determined. This is a point to be considered in future studies of Cork Harbour economical dimension using such frameworks as CCS. The difficulties in obtaining precise economics input of the study area makes this indicator a low-confidence indicator. Proportions of managers, directors and senior officials who are female in South-West region in 2017 very well represents the equality in gender representation in higher ranking employment positions. However, this is a proxy indicator, again, taken from a South-West region which is a NUTS

segregated region which lowers the confidence level. A more precise and specific dataset could increase the confidence level of this indicator. With such indicators and dataset with an already established boundaries (by regions/districts/economic regions), tailored study areas find difficulties. Taking an already established boundary/region will increase the credibility of these data. Employment patterns in the system area is also something that is qualitatively evaluated (in more visual way) with no fitting scoring methodology. Overall, this category itself is a category with low confidence although the indicators have potentials. The information made available are divided by NUTS region and this reduces the credibility of the data available when used in tailored system areas.

Infrastructure category attained a 'satisfactory' status. Energy supply in terms of percentage of population with access to central heating has attained 'satisfactory'. Half of the population do not have access to central heating in the county; this lacks in preparedness for disaster emergencies (Phillips, 2017). However, it is to note that this data is a proxy indicator taken from county level. Transportation is a critical infrastructure and disruption to its components can impact the economic and social well-being of a community (Rodrigue, 2020). Means of transport looks at carbon footprint which might not necessarily translates to preparedness against climate emergencies but rather the contribution in terms of carbon footprints. Access to transport is crucial when emergencies arise (Godfrey, et al., 2019); half of the population in Cork County has less than 10 frequencies of access to public transport. This indicator is another low-confidence indicator due to it being extracted from a dataset representing Cork County on a county level. Tourism sub-category was evaluated using Travel and Tourism Competitiveness index. This index looks at achieving a sustainable and inclusive travel & tourism industry capable of contributing effectively to international economic development (Calderwood & Soshkin, 2019). This is a valuable indicator as the harbour is in vulnerable position of coastal hazards while some areas in the system are of important tourism interests. However, this index represents Ireland as a country creating a bias in the results.

Economic well-being category attained a 'good' status; the category is with a low confidence as the two indicators used are all proxy indicators extracted from a regional level and a country level. GINI index was used to evaluate the wealth inequality, and consistent poverty rate was used to evaluate the income status. The two indicators, in a sense, evaluate the same concept (i.e., income circumstances) but produced different results; 'good' and 'satisfactory', respectively. This is a good example of bias and uncertainty prevailing in proxy data extracted from county or country level.

Renewable energy industry and extractive industry are indicators for industry category which attained a 'good' status. Renewable energy contribution is 'good' as the wind developments in the system area contributes to about 17% of the Ireland's total installed wind power. This status could switch to an 'excellent' status due to more offshore renewable energy development plans in the system area by the private sector by companies such as Green Rebel Marine, Irish Mainport Holdings, Doyle Shipping Group, Simply Blue Group, DP Energy and Port of Cork (Hoare, 2021). For extractive industry, the indicator, offshore capture fisheries value is also specific to the system area which increases the overall confidence of the category score. This reflects the economic input of Cork Harbour in general even though other economic sectors such as pharmaceutical sectors and trading sector are not taken into account. This is something that can be improved for future studies of such framework.

Dependency is a category with very low confidence. It attained a 'satisfactory' status but this is very subjectively evaluated and can be interpreted in many ways. The author mentioned two possible ways of evaluating this: low density of coastal-related jobs being favourable in terms of disaster impacts, and low number of coastal-related jobs being unfavourable in terms of the dependency and livelihood; the latter was chosen. However, this is a system area that is a harbour with several ports for trading and this contributes to different types of jobs available in the area, not just coastal related jobs like fisheries and aquaculture. Most of the port activities and trading is managed by Port of Cork Company (Port of Cork, n.d.) but Cork Harbour is not just about port activities but also hosting blue economy and green energy sectors (Afloat.ie, 2021). This kind of theory might apply to other coastal areas that solely depend on fisheries (ref) but not harbours and ports. This is especially important when looking at Cork Harbour's contribution to the whole of South Ireland's economy.

5.1.4 Governance and Policy

TABLE 26: GOVERNANCE AND POLICY DIMENSION INDICATORS BREAKDOWN.

Category	Sub-category	Indicators	Score	Final Score
1. Organisations	Civil and NGOs	Number of Irish NGOs under Irish Environmental Network	Satisfactory	Satisfactory
2. Law and Justice	Legislation	Number of protected areas	Excellent	Good
	Enforcement	Types of environmental services provided by Cork County Council	Satisfactory	

3. Representation and power	Gender	Percentage of seats in local government held by women in South-West region in 2019	Satisfactory	Satisfactory
4. Legitimacy and accountability	Voice and accountability	WorldBank data (2020)	Excellent	Excellent
	Control of corruption	WorldBank data (2020)	Excellent	
5. Resource management	Management	Aquaculture and Foreshore management. Acts, regulations and licences	Good	Good

[Results]

Organisations category as in presence of environmental civil and NGOs is given a 'satisfactory' status. Law and justice category is in 'good' status with 'excellent' status in legislation sub-category and 'satisfactory' status in enforcement sub-category. Representation and power is 'satisfactory' in terms of gender distribution in local government. Irish government legitimacy and accountability is 'excellent'. Management of coastal resources is in 'good' status. This gives the overall status of governance and policy dimension as 'good' (table. 26 & fig. 13).

FIGURE 13: CORK HARBOUR'S GOVERNANCE AND POLICY DIMENSION IS IN 'GOOD' STATUS.

[Discussion]

Governance and policy dimension attained a 'good' status. All the indicators used to evaluate this dimension are proxy indicators, meaning they were extracted from either a county level or country level. This gives low confidence results for this dimension.

Organisations category attained a 'satisfactory' status. This is qualitatively measured, and this evaluates the presence of civil and NGOs. Due to the qualitative scoring methodology and the proxy indicator, this category is given a medium status 'satisfactory'; the presence of NGOs and civil organisations could be measured quantitatively by numbers, but this does not necessarily represent their competency. This indicator was suggested in CCS framework, but this can be improved for future studies; instead of civil and NGO organisations, organisation structures of government bodies that are in charge of coastal zone areas might be more fitting.

Law and justice category attained a 'good' status. However, scoring methodology of this sub-category is also of low confidence; both indicators were qualitatively evaluated. Presence of protected areas, like SPAs and SACs, is used to evaluate the establishment of legislations which shows the competence of the government in terms of adhering to EU directives. Types of environmental services provided by Cork County Council is used to evaluate the enforcement competency of the government. Competency and compliance promotion of the Irish government are well co-ordinated, but non-compliance levels are relatively high.

Representation category was evaluated using gender representation in local government seats. This is a proxy indicator which the data was extracted from a regional level. Using gender equality might not be the best way to evaluate representation and power but this is the most suitable data available which also narrowed down to a regional level rather than evaluating the whole of Ireland as a country. This dataset was compared to other regions within Ireland.

Legitimacy and accountability were evaluated using data from the WorldBank and sees where Ireland stands in the percentile compared to other countries. However, this does not necessarily represent the legitimacy, accountability, and control of corruption of Cork County Council. Furthermore, the author would like to point out different authorities involved in managing the harbour; Port of Cork Company is its own statutory body and other independent bodies like these were not taken into account of WorldBank data for measuring legitimacy and accountability.

Resources management looked at the regulations and acts that are present. The credibility for this category is higher as the regulations and acts apply to needed expertise,

despite the system location, and the existence of these indicate that the management of harbour is also in plan under these regulations and acts.

5.1.5 Discussion on overall results

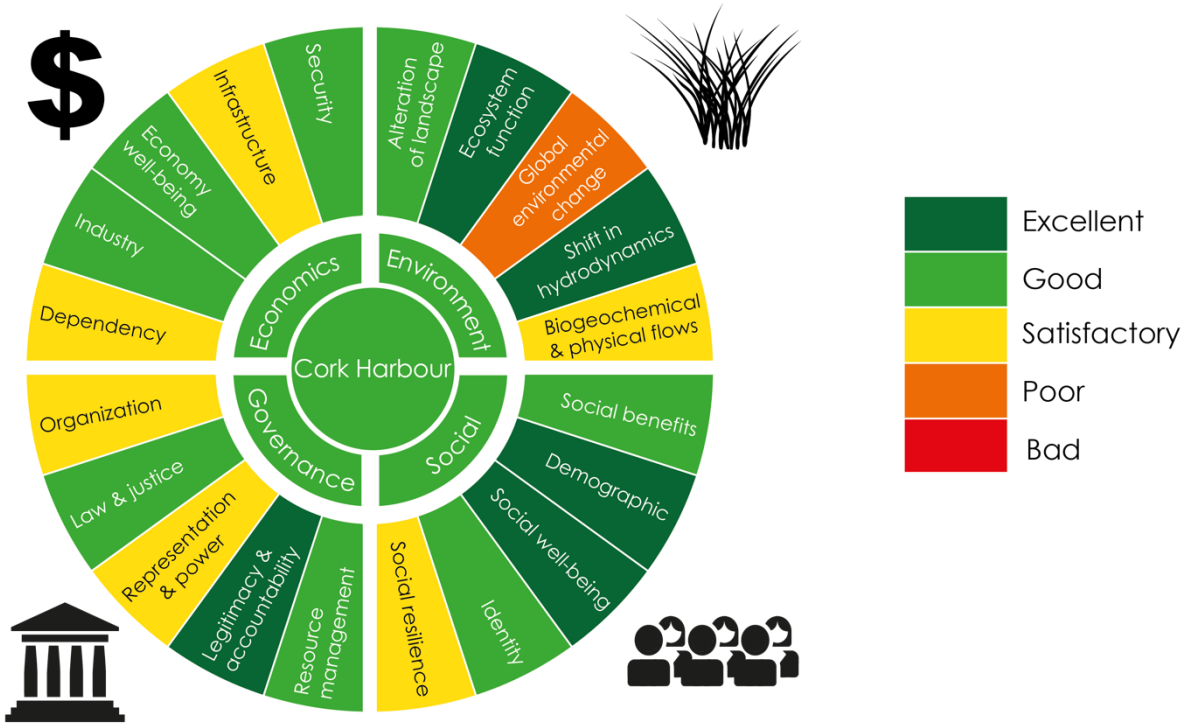

FIGURE 14: CCS REPRESENTATION OF CORK HARBOUR.

The system overall has a 'good' status (fig. 14) despite one 'poor' category and a few 'satisfactory' categories in the system. This status puts Cork Harbour study area in a resilient position against climate extremes; all four-dimensional aspects were evaluated and found to be in 'good' status.

The main difficulties the author came across are the difficulties in scoring the indicators, especially ones that involved qualitative scoring methods having to extract data from county, regional or country level reduced the confidence level of the results. The 'good' status attained by the system could shift to a 'satisfactory' level with more precise indicators and more credible scoring methods. Incorporating statistical evaluation is a suggestion that can greatly increase the credibility of the results. Due to the nature of the study area as the system boundary is devised by the author rather than a politically divided district, like a city, a town or a village. The areas in the harbour are under management of different municipal districts

and each district has their own local governmental bodies. This makes it difficult for most indicators to be measured accurately with a theoretical boundary.

5.2 Discussion on indicators distribution

FIGURE 15: INDICATORS DISTRIBUTION.

The four dimensions constituting the CCS framework are Environment and Ecology, Social and cultural, Economics, and Governance and Policy. Each dimension consists of categories of indicators to measure sustainability. The indicators applied in four dimensions are found to be unevenly distributed (fig.15). The environment and ecology dimension has the highest distributions of indicators while governance and policy dimension have the lowest. This alone shows that there is a biasness in availability of the indicators between dimensions as well as the certainty between them.

This can be concluded that the environmental indicators are more readily available for public access, and also can be easily used as indicators. Another possibility is due to the comprehensive databases like maps and GIS data being available to public from Environmental Protection Agency (Environmental Protection Agency, n.d.). These data, paired with maps, allow the users to easily pinpoint the area of interest and abstract the environmental information wanted. There are also several environmental impact assessments or environmental

assessments produced for the area due to several EU directives catered towards the protection of environment: example like Lee-Cork Harbour Catchment Assessment (Environmental Protection Agency, 2018). (Chen & Zhang, 2021) studies on sustainability in Northeast China revealed that environmental indicators are the most important factor affecting sustainability; CCS framework on Cork Harbour also displayed environmental dimension as the biggest among others thus indicating it as the most 'important' aspect of sustainability, which might not necessarily be the case.

[Chapter 6 – Conclusion]

Climate Change brings about natural disasters and impacts to ecosystem services which subsequently influence the society and the economy of the population. The economic status, geographic placement and equity issues of the population determine the vulnerability of the very population. Adaptation capacity and resilience of the population come into play when withstanding against the impacts unleashed by climate extremes. Human adaptation and ecological adaptation vary from local to global scale and the ability for the population to reorganize itself depends on the response capacity, adaptive capacity, and the credibility of the governance structure. Extreme disaster events and risks due to changing climate is not just a prediction anymore where many nations and regions have felt the damage of these climatic extremes. International bodies like United Nations have always stressed on the sustainable developments to reduce or slow down the changing climate. However, we have come to a point where stopping or reverting these climatic conditions are near impossible. Adaptation and resilience of the system is the route to minimize the damage and maximise the coping capacities of the systems. Gaps between current adaptation and the adaptation needed for future have been observed and it is important for policymakers to have a clear view of what the shortcomings and vulnerabilities are and to avoid maladaptation. Measuring sustainability and resilience serves this purpose, especially the selection process of suitable indicators.

The Circle of Coastal Sustainability framework assessed the sustainability of Cork Harbour from the aspects of four dimensions – Policy & Government, Economics, Social & Culture, and Environment and Ecology. The framework evaluated Cork Harbour to be resilient against sudden climate disasters from all four dimensions. However, the evaluation process encountered shortcomings, such as a difficulty in selecting locally relevant indicators with high certainty due to the locality of the study area and weak scoring methods applied to indicators.

Biases have also been recognized along the study; in terms of the number of indicators available and/or their relevancy to the dimension being assessed. For example, many indicators in the environment and ecology dimension can be evidently linked to issues occurring in the system whereas most of the indicators for other dimensions are more generalized and are proxy indicators. The harbour is heavily linked and interdependent with nearby towns and cities and contributes a lot to Cork County in general. Cork Harbour is connected to towns and cities of which are under different municipal districts and this segregation results in difficulties of choosing suitable indicators. This questions the adaptive ability and usefulness of the framework; the Circles of Coastal Sustainability framework is more suitable for study areas with accordingly established boundaries (especially governmental structures). Frameworks like Circles of Coastal Sustainability, with the focus and the means it provides, can affectively aid the government and private sectors to identify risks and shortcomings, steer investments towards actions on adaptation and resilience, while avoiding maladaptation. In relation to water and coastal management, CCS has potential to be a very powerful tool that can assess the impacts of water and coastal hazards on the coastal areas and how the resilience of the system against these climate hazards.

Answering the main research question, "Can CCS framework be integrated into legal instruments for climate change resilience and climate change adaptation?", with an improved methodology, the framework can be integrated into legal plannings and developments in the area and is an excellent framework that will steer the competent authority to needed directions attention towards a poorly performing dimension for improvement towards resilience and sustainability.

Cork Harbour is no doubt one of the significantly important regions in the Republic of Ireland, in terms of economic development, international networking and ecological importance. It is a complex system where diverse stakeholders and factors interact with each other. The harbour is also on its course for more development plans which means the existing environmental problems and pressures will be further intensified. Circles of Coastal Sustainability framework will assist in assessing the sustainability of Cork Harbour which in turn can be employed by decision-makers in delivering mitigation and adaptation strategies to make Cork Harbour a more resilient system. Using Cork Harbour as a pilot study, Ireland can apply the framework on a large scale on its coastal areas where climate hazards are most prominent. If utilised to its full extent, the framework has capability to aid policy and legal instruments and reinforce their effectiveness.

Dissemination and exploitation of results

This section states the disseminations of the results of this thesis.

Audience	Tools	Status
Scientific community	Journal article	In progress
Scientific community	Presentation at Sustainability Research & Innovation Congress 2022	Done
Scientific community	Presentation at UN Ocean Decade Conference	Done
Relevant stakeholders	An oral presentation/poster	In progress

Bibliographys

Afloat.ie, 2021. *€120m Green Energy Facility Planned for Cork Harbour at Aghada.* [Online]
Available at: https://afloat.ie/marine-environment/power-from-the-sea/item/50432-120m-green-energy-facility-planned-for-cork-harbour
[Accessed 31 March 2022].

Alencar, N. M. P., 2018. *Circles of Coastal Sustainability Framework,* Cadiz: Erasmus Munduds Joint Master in Water and Coastal Management.

Alencar, N. M., Tissier, M. L., Paterson, S. K. & Newton, A., 2020. Circles of Coastal Sustainability: A Framework for Coastal Management. *Sustainability,* 12(12).

Algan, Y., Brunello, G., Goreichy, E. & Hristova, A., 2021. *Boosting Social and Economic Resilience in Europe by Investing in Education,* Luxembourg: Publications Office of the European Union.

Aly, E., Elsawah, S. & Ryan, M. J., 2022. Aligning the achievement of SDGs with long-term sustainability and resilience: An OOBN modelling approach. *Environmental Modelling & Software*, Volume 150.

Barros, V. R. & Field, C. B., 2014. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects.*. s.l.:Cambridge University Press.

Beaches.ie, 2022. *Fountainstown.* [Online]
Available at: https://www.beaches.ie/find-a-beach/#/beach/IESWBWC050_0000_0100
[Accessed 3 June 2022].

Beaches.ie, 2022. *Inch Strand.* [Online]
Available at: https://www.beaches.ie/find-a-beach/#/beach/BPNBF050000220001#beach-single-map
[Accessed 3 June 2022].

Black, R., 2013. *A brief history of climate change.* [Online]
Available at: https://www.bbc.com/news/science-environment-15874560
[Accessed 28 March 2022].

Brundtland, G. H., 1987. *Our Common Future: Report of the World Commission on Environment and Development.,* Oxford: Oxford University Press.
Burcham, C., 2021. *Resiliency as we age.* [Online]
Available at: https://extension.illinois.edu/blogs/your-health/2021-01-20-resiliency-we-age
[Accessed 13 June 2022].

Calderwood, L. U. & Soshkin, M., 2019. *Travel & Tourism Competitiveness Report 2019,* Geneva: World Economic Foru.

Castleden, M., McKee, M., Murray, V. & Leonardi, G., 2022. Resilience thinking in health protection. *Journal of Public Health,* 33(3), pp. 369-377.

Central Statistics Office, 2016. *Census 2016 Sapmap Area: County Cork County.* [Online]
Available at:
http://census.cso.ie/sapmap2016/Results.aspx?Geog_Type=CTY31&Geog_Code=2AE1962914A313A3E055000000000001#SAPMAP_T10_1004
[Accessed 11 May 2022].

Central Statistics Office, 2016. *Measuring Distance to Everyday Services in Ireland.* [Online]
Available at: https://www.cso.ie/en/releasesandpublications/ep/p-mdsi/measuringdistancetoeverydayservicesinireland/publictransportservices/#:~:text=The%20nearest%20public%20transport%20stop,people%20were%20within%20500%20metres.
[Accessed 1 June 2022].

Central Statistics Office, 2017. *Press Statement Census 2016 Results Profile 9 - Health, Disability and Carers.* [Online]
Available at:
https://www.cso.ie/en/csolatestnews/pressreleases/2017pressreleases/pressstatementcensus2016resultsprofile9-healthdisabilityandcarers/
[Accessed 3 June 2022].

Central Statistics Office, 2018. *Survey on Income and Living Conditions.* [Online]
Available at:
https://www.cso.ie/en/methods/surveybackgroundnotes/surveyonincomeandlivingconditions/
[Accessed 19 April 2022].

Central Statistics Office, 2018. *UN SDG's Goal 1 - No Poverty.* [Online]
Available at: https://www.cso.ie/en/statistics/unsustainabledevelopmentgoals/unsdgsgoal1-nopoverty/
[Accessed 10 May 2022].

Central Statistics Office, 2019. *Ireland's UN SDGs 2019 - Report on Indicators for Goal 5 Gender Equality.* [Online]
Available at: https://www.cso.ie/en/releasesandpublications/ep/p-sdg5/irelandsunsdgs2019-reportonindicatorsforgoal5genderequality/equality/
[Accessed 2 June 2022].

Central Statistics Office, 2019. *Ireland's UN SDGs 2019 - Report on Indicators for Goal 5 Gender Equality.* [Online]
Available at: https://www.cso.ie/en/releasesandpublications/ep/p-sdg5/irelandsunsdgs2019-reportonindicatorsforgoal5genderequality/
[Accessed 2 May 2022].

Central Statistics Office, 2019. *Ireland's UN SDGs 2019 - Report on Indicators for Goal 7 Affordable and Clean Energy.* [Online]
Available at: https://www.cso.ie/en/releasesandpublications/ep/p-sdg7/irelandsunsdgs2019-reportonindicatorsforgoal7affordableandcleanenergy/affordableandcleanenergy/#d.en.275673
[Accessed 26 April 2022].

Central Statistics Office, 2019. *UN SDG's Goal 7 - Affordable and Clean Energy.* [Online]
Available at: https://www.cso.ie/en/statistics/unsustainabledevelopmentgoals/unsdgsgoal7-affordableandcleanenergy/
[Accessed 2 June 2022].

Central Statistics Office, 2020. *Number of indicators sourced for SDG 1.* [Online]
Available at: https://irelandsdg.geohive.ie/pages/goal1
[Accessed 3 June 2022].

Chen, Y. & Zhang, D., 2021. Evaluation and driving factors of city sustainability in Northeast China: An analysis based on interaction among multiple indicators. *Sustainable Cities and Societies,* Volume 67.

Climate-ADAPT, 2016. *Integrated management and adaptation strategies for Cork Harbour, Ireland.* [Online]
Available at: https://climate-adapt.eea.europa.eu/metadata/case-studies/integrated-management-and-adaptation-strategies-for-cork-harbour-ireland/#challenges_anchor
[Accessed 1 June 2022].

Climate-Adapt, 2021. *EU Adaptation Strategy.* [Online]
Available at: https://climate-adapt.eea.europa.eu/eu-adaptation-policy/strategy
[Accessed 1 June 2022].

Cohen, O. et al., 2016. Community Resilience throughout the Lifespan – The Potential Contribution of Healthy Elders. *PLOS One,* 11(2).

Conroy, M., 2011. *Government Signs off on ´40m to Clean Up Haulbowline Waste Site.* [Online]
Available at: https://afloat.ie/port-news/cork-harbour-news/item/17049-govt-signs-off-on-%E2%82%AC40m-to-clean-up-haulbowline-waste-site/
[Accessed 23 September 2021].

Convention on Biological Diversity, 2020. *Aichi Biodiversity Targets.* [Online]
Available at: https://www.cbd.int/sp/targets/
[Accessed 28 April 2022].

Cork Chamber, 2021. *Cork Harbour 2025 Ready to Float - Offshore Wind,* Cork: Cork Chamber.

Cork City Council, 2019. *Climate Change Adaptation Strategy 2019-2024,* Cork: s.n.

Cork County Council, 2011. *Cork Harbour Study Draft,* Cork: Cork County Council.

Cork County Council, 2016. *Public Water Supply Monitoring,* Cork: Cork County Council.

Cork County Council , 2019. *Cork County Development Plan Review - Economy and Employment,* Cork: Cork County Council .

Cork County Council, 2019. *Cork County Development Plan Review Economy and Employment,* Cork: Cork County Council Publications.

Cork County Council, 2020. *Cork County Development Plan Review: Economy and Employment Backgorund document No. 6. ,* Cork: Cork City Council Publications.

Cork County Council, 2021. *Draft Cork County Development Plan 2021,* Cork: Cork County Council.

Cork County Council, n.d. *Climate Adaptation Strategy,* Cork: Cork County Council.

Cork County Council, n.d. *Cork County Council.* [Online]
Available at: https://www.corkcoco.ie/en/your-county-council/strategic-plans-policies
[Accessed 20 September 2021].

Cork County Council, n.d. *Environment.* [Online]
Available at: https://www.corkcoco.ie/en/environment
[Accessed 23 May 2022].

CSO statistical publication, 2017. *Census of Population 2016 – Profile 9 Health, Disability and Carers.* [Online]
Available at:
https://www.cso.ie/en/csolatestnews/pressreleases/2017pressreleases/pressstatementcensus2016resultsprofile9-healthdisabilityandcarers/
[Accessed 19 May 2022].

CSO statistical publication, 2020. *Sustainable Development Goal 1.* [Online]
Available at: https://irelandsdg.geohive.ie/pages/goal1
[Accessed 18 May 2022].

Cummins, V., n.d. *Coastal Projects and Case Studies: Cork Harbour,* s.l.: SPICOSA.
de Groot, R. S., Wilson, M. A. & Boumans, R. M., 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics,* Volume 41, pp. 393-408.

Department of Agriculture, Food and the Marine, 2022. *Aquaculture & Foreshore Management.* [Online]
Available at: https://www.gov.ie/en/publication/fcd20-aquaculture-foreshore-management/
[Accessed 27 May 2022].

Department of the Taoiseach, 2020. *Climate Action Plan 2019 ,* s.l.: Department of Communications, Climate ACtion & Environment.

Derissen, S., Quaas, M. F. & Baumgärtner, S., 2011. The relationship between resilience and sustainability of ecological-economic systems. *Ecological Economics,* 70(6), pp. 1121-1128.

Desmond, M., O'Brien, P. & McGovern, F., 2008. *A Summary of the State of Knowledge on Climate Change Impacts for Ireland,* s.l.: Environmental Protection Agency, Ireland.

Dijk, M. et al., 2017. Sustainability assessment as problem structuring: three typical ways. *Sustainability Science,* Volume 12, pp. 305-317.

Eastwood, A. et al., 2013. *Nature conservation and ecosystem service delivery,* Peterborough: JNCC.

EchoLive, 2021. *Webinar to give insight into the growth of Cork harbour,* Cork: EchoLive.

Edwards, R. & Hogarth, P., 2021. Mean Sea Level and Tidal Change in Ireland since 1842: A case study of Cork. *Ocean Science.*

Environmental Protection Agency, 2018. *Lee-Cork Harbour Catchment Assessment 2010-2015 (HA 19)* , s.l.: Environmental Protection Agency Ireland.

Environmental Protection Agency, 2022. *EPA Maps.* [Online]
Available at: https://gis.epa.ie/EPAMaps/default
[Accessed 1 May 2022].

Environmental Protection Agency, n.d. *EPA Maps.* [Online]
Available at: https://gis.epa.ie/EPAMaps/default
[Accessed 31 March 2022].

Environmental Protection Agency, n.d. *What impact will climate change have on Ireland?.* [Online]
Available at: https://www.epa.ie/environment-and-you/climate-change/what-impact-will-climate-change-have-for-ireland/
[Accessed 20 Septmeber 2021].

European Commission, 2003. *No 13 - Overall Approach to the Classification of Ecological Status and Ecological Potential,* Luxembourg: Office for Official Publications of the European Communities .

European Commission, 2010. *Water Framework Directive Factsheet,* Luxembourg: Publications Office of the European Union.

European Commission, n.d. *Bathing water quality.* [Online]
Available at: https://ec.europa.eu/environment/water/water-bathing/summary.html
[Accessed 15 June 2022].

European Commission, n.d. *Natura 2000: Sites - Birds Directive.* [Online]
Available at: https://ec.europa.eu/environment/nature/natura2000/sites_birds/index_en.htm
[Accessed 11 June 2022].

European Union, 2014. *S.I. No. 122/2014 - European Union (Drinking Water) Regulations 2014,* s.l.: European Union.

European Union, 2020. *Regulations, Directives, and other acts.* [Online]
Available at: https://europa.eu/european-union/law/legal-acts_en
[Accessed 19 September 2021].

European Union, 2021. *The EU in Brief.* [Online]
Available at: https://europa.eu/european-union/about-eu/eu-in-brief_en#from-economic-to-

political-union
[Accessed September 19 2021].

Foote, K. E. & Azaryahu, M., 2009. Sense of Place. In: R. Kitchin & N. Thrift, eds. *International Encyclopedia of Human Geography.* s.l.:Elsevier Science.

Forsyth, T., 2018. Is resilience to climate change socially inclusive? Investigating theories of change processes in Myanmar. *World Development,* Volume 111, pp. 13-26.

Geological Survey Ireland, 2021. *What are the effects of climate change on Ireland?,* s.l.: Geological Survey Ireland.

Godfrey, J., Saliceto, G. & Yegidis, R., 2019. ole of Public Transportation in a Natural Disaster State of Emergency Declaration. *Sage Journals,* 2673(5).

Gunnarsdottir, I., Davidsdottir, B., Worrell, E. & Sigurgeirsdottir, S., 2022. Indicators for sustainable energy development: An Icelandic case study. *Energy Policy,* Volume 164.

Halkos, G. & Argyropoulou, G., 2022. Using environmental indicators in performance evaluation of sustainable development health goals. *Ecological Economics,* Volume 192.

Heink, U. & Kowarik, I., 2010. What are indicators? On the definition of indicators in ecology and environmental planning. *Ecological Indicators,* 10(3), pp. 584-593.

Hoare, P., 2021. *Cork Harbour at centre of renewable energy revolution.* [Online]
Available at: https://www.irishexaminer.com/news/spotlight/arid-40307939.html#:~:text=Cork%20Harbour%20is%20in%20the,%2C%20and%20Port%20of%20Cork.%22
[Accessed 12 June 2022].

HUD User, 2017. *Combining Energy Efficiency and Disaster Mitigation Efforts in Residential Properties.* [Online]
Available at: https://www.huduser.gov/portal/periodicals/em/spring17/highlight2.html
[Accessed 2 June 2022].

IEN, n.d. *Below is a list of our Member Organziations.* [Online]
Available at: https://ien.ie/our-members/
[Accessed 2 May 2022].

IMCORE, 2011. *Cork Harbour case study.* [Online]
Available at: http://www.coastaladaptation.eu/index.php/en/9-experiences/cork-harbour
[Accessed 1 June 2022].

INFOMAR, 2020. *ArcGIS StoryMaps.* [Online]
Available at: https://storymaps.arcgis.com/stories/5f4c2b708857468baf4033fed94f5453
[Accessed 5 September 2021].

INSPIRE, n.d. *WFD Transitional Water.* [Online]
Available at:
https://inspire.ec.europa.eu/featureconcept/WFDTransitionalWater#:~:text=Definition%3A,s

ubstantially%20influenced%20by%20freshwater%20flows.
[Accessed 18 June 2022].

Intergovernmental Panel on Climate Change, 2018. *Appendix A to the Principles Governing IPCC Work.* [Online]
Available at: https://www.ipcc.ch/site/assets/uploads/2018/09/ipcc-principles-appendix-a-final.pdf
[Accessed 28 March 2022].

Irish Water, n.d. *Cork Lower Harbour Main Drainage Project.* [Online]
Available at: https://www.water.ie/projects/local-projects/cork-lower-harbour/
[Accessed 20 September 2021].

Jacobs, S. et al., 2013. Biodiversity and Ecosystem Services. In: *Ecosystem Services: Global Issues, Local Practices.* s.l.:Elsevier, pp. 29-40.

Juwana, I., Muttil, N. & Perera, B. J., 2012. Indicator-based water sustainability assessment - A review. *Science of The Total Environment,* Volume 438, pp. 357-371.

Lei, Y. et al., 2014. Rethinking the relationships of vulnerability, resilience,and adaptation from a disaster risk perspective. *Natural Hazards,* 70(1).

Lenihan, A. C. & McGuirk, H., 2017. *The Economic Impact of the Marine Leisure Industry on Cork Harbour ,* s.l.: SWORD-South West Open Research Deposit.

Liverman, D. M., Hanson, M. E., Brown, B. J. & Merideth Jr., R. W., 1988. Global Sustainability: Toward Measurement. *Environmental Management,* Volume 12, pp. 133-143.
Local Government Act 2019 (Transfer Day) Order 2019 (2019).

Masson-Delmotte, V. et al., 2021. *IPCC,2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group 1 to the Sixth Assessment Report of the the Intergovernmental Panel on Climate Change. ,* s.l.: Cambridge University Press.

Mattson, J. et al., 2021. Transportation, community quality of life, and life satisfaction in metro and non-metro areas of the United States. *Wellbeing, Space and Society,* Volume 2.
MET eireann, 2022. *Monthly Data-Roches Point.* [Online]
Available at: https://www.met.ie/climate/available-data/monthly-data
[Accessed 2 May 2022].

McCarthy, K. 2019. *The Little book of Cork Harbour.* Dublin: The History Press.

Meyer, W., 2014. *Urban Legends.* [Online]
Available at: https://news.colgate.edu/scene/2014/11/urban-legends.html
[Accessed 2 June 2022].

Nash, S., Berry, A. & Hartnett, M., 2005. Nutrient dynamics in Cork Harbour. In: C. A. Brebbia & J. S. Antunes do Carmo, eds. *River Basin Management 3.* s.l.:WIT Press.

National Geographic Society, n.d. *Learn With Us.* [Online]
Available at: https://education.nationalgeographic.org/resource/cove
[Accessed 19 June 2022].

National Parks and Wildlife Service, 2014. *Cork Harbour Special Protection Area,* Cork: s.n.

National Parks and Wildlife Services, n.d. *Great Island Channel SAC.* [Online]
Available at: https://www.npws.ie/protected-sites/sac/001058
[Accessed 11 June 2022].

Norton, D., Hynes, S. & Boyd, J., 2018. *Valuing Ireland's Blue Ecosystem Services,* Galway: NUI Galway Publications.

O'Connor , I. et al., 2011. *Composition and Sources of Particulate Air Pollution in a Port Environment, Cork, Ireland,* Wexford: Environmental Protection Agency.

OECD, 2001. *Glossary of Statistical Terms.* [Online]
Available at:
https://stats.oecd.org/glossary/detail.asp?ID=2480#:~:text=Social%20benefits%20are%20current%20transfers,housing%2C%20education%20or%20family%20circumstances.
[Accessed 2 May 2022].

OECD, 2021. *OECD Environmental Performance Reviews IRELAND,* Paris: OECD Publishing.

Office of Public Works, n.d. *About Flood Maps.* [Online]
Available at: https://www.floodinfo.ie/about_floodmaps/
[Accessed 12 May 2022].

O'Mahony, C., Gray, S., Gault, J. & Cummins, V., 2015. ICZM as a framework for climate change adaptaiton action - Experience from Cork Harbour, Ireland. *Marine Policy,* Volume 111.

Our World in Data, 2020. *Which form of transport has the smallest carbon footprint?.* [Online]
Available at: https://ourworldindata.org/travel-carbon-footprint
[Accessed 24 May 2022].

Parliamentary Commissioner for the Environment, 1996. *THE MANAGEMENT OF SUBURBAN AMENITY VALUES,* Wellington: Parliamentary Commissioner for the Environment.

Pelling, M., 2011. *Adaptation to Climate Change from resilience to transformation.* 1st Edition ed. New York: Routledge .

Phillips, C., 2017. *Combining Energy Efficiency and Disaster Mitigation Efforts in Residential Properties,* s.l.: Office of Policy Development and Research.

Port of Cork Company, 2021. *Weather and Tides.* [Online]
Available at: https://www.portofcork.ie/index.cfm/page/weatherconditions
[Accessed 20 September 2021].

Port of Cork, n.d. *Port History.* [Online]
Available at: https://www.portofcork.ie/index.cfm/page/porthistory
[Accessed 14 September 2021].

Port of Cork Company, n.d. *Port of Cork.* [Online]
Available at: https://www.portofcork.ie/index.cfm
[Accessed 19 September 2021].

Port of Cork, n.d. *Port Operations.* [Online]
Available at: https://www.portofcork.ie/index.cfm/page/portoperations
[Accessed 31 March 2022].

Pörtner, H.-O., D.C. Roberts, H. Adams, I. Adelekan, C. Adler, R. Adrian, P. Aldunce, E. Ali, R. Ara Begum, B. Bednar-Friedl, R. Bezner Kerr, R. Biesbroek, J. Birkmann, K. Bowen, M.A. Caretta, J. Carnicer, E. Castellanos, T.S. Cheong, W. Chow, G. Cissé, S. Clayton, A. Constable, S. Cooley, M.J. Costello, M. Craig, W. Cramer, R. Dawson, D. Dodman, J. Efitre, M. Garschagen, E.A. Gilmore, B. Glavovic, D. Gutzler, M. Haasnoot, S. Harper, T. Hasegawa, B. Hayward, J.A. Hicke, Y. Hirabayashi, C. Huang, K. Kalaba, W. Kiessling, A. Kitoh, R. Lasco, J. Lawrence, M.F. Lemos, R. Lempert, C. Lennard, D. Ley, T. Lissner, Q. Liu, E. Liwenga, S. Lluch-Cota, S. Löschke, S. Lucatello, Y. Luo, B. Mackey, K. Mintenbeck, A. Mirzabaev, V. Möller, M. Moncassim Vale, M.D. Morecroft, L. Mortsch, A. Mukherji, T. Mustonen, M. Mycoo, J. Nalau, M. New, A. Okem (South Africa), J.P. Ometto, B. O'Neill, R. Pandey, C. Parmesan, M. Pelling, P.F. Pinho, J. Pinnegar, E.S. Poloczanska, A. Prakash, B. Preston, M.-F. Racault, D. Reckien, A. Revi, S.K. Rose, E.L.F. Schipper, D.N. Schmidt, D. Schoeman, R. Shaw, N.P. Simpson, C. Singh, W. Solecki, L. Stringer, E. Totin, C.H. Trisos, Y. Trisurat, M. van Aalst, D. Viner, M. Wairu, R. Warren, P. Wester, D. Wrathall, and Z. Zaiton Ibrahim, 2022: Technical Summary. [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: *Climate Change 2022: Impacts, Adaptation, and Vulnerability.* Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. In Press.

Pradere, B. et al., 2022. Climate-smart Actions in the Operating Theatre for Improving Sustainability Practices: A Systematic Review. *European Urology.*

Pugh, D. T. et al., 2021. Mean sea level and tidal change in Ireland since 1842: a case study of Cork. *Ocean Science,* 17(6), pp. 1623-1637.

Pure Cork, n.d. *Weather & Climate.* [Online]
Available at: https://purecork.ie/plan-your-trip/about-cork/weather-climate
[Accessed 18 September 2021].

Redman, C. L., 2014. Should sustainability and resilience be combined or remain distinct pursuits?. *Ecological Society,* 19(2).

Rodrigue, J.-P., 2020. Transportation, Disruptions and Resilience. In: *The Geography of Transport Systems.* New York: Routledge.

RPS Group, 2011. *Irish Coastal Protection Strategy Study Phase 3 - South Coast,* Belfast: Office of Public Works.

Sala, S., Ciuffo, B. & Nijkamp, P., 2015. A systemic framework for sustainability assessment. *Ecological Economics,* Volume 118, pp. 314-325.

Simmons, D., 2020. *What is 'climate justice'?.* [Online]
Available at: https://yaleclimateconnections.org/2020/07/what-is-climate-justice/
[Accessed 11 May 2022].

Sustainable Energy Authority of Ireland, 2020. *Electricity.* [Online]
Available at: https://www.seai.ie/data-and-insights/seai-statistics/key-statistics/electricity/
[Accessed 26 May 2022].

Trodd, W. et al., 2021. *Water Quality in 2020: An Indicators Report,* Wexford: Environmental Protection Agency.

Tsakiridis, A. et al., 2019. *Ireland's Ocean Economy,* Galway: NUI Galway Publishing.

UN CC:Learn, 2021. *A newly released report by UNDP confirms that education is key to addressing climate change.* [Online]
Available at: https://www.uncclearn.org/news/a-newly-released-report-by-undp-confirms-that-education-is-key-to-addressing-climate-change/
[Accessed 11 May 2022].

UN General Assembly, 2015. *Transforming our world: the 2030 Agenda for Sustainable Development,* s.l.: UN General Assembly.

United Nations, n.d. *Education is key to addressing climate change.* [Online]
Available at: https://www.un.org/en/climatechange/climate-solutions/education-key-addressing-climate-change
[Accessed 11 May 2022].

UNWTO, n.d. *Transforming Tourism for Climate Action.* [Online]
Available at: https://www.unwto.org/sustainable-development/climate-action
[Accessed 2 June 2022].

Van Oord Dredging & Marine Contractors, 2012. *Environmental aspects of Cork Harbour dredging.,* s.l.: Van Oord Marine Ineguity.

World Bank, 2018. *Gini Index.* [Online]
Available at: https://data.worldbank.org/indicator/SI.POV.GINI?locations=IE&view=map
[Accessed 22 May 2022].

World Bank, 2020. *Control of Corruption.* [Online]
Available at:
https://govdata360.worldbank.org/indicators/hf0ef1ed3?country=BRA&indicator=369&viz=line_chart&years=1996,2020
[Accessed 27 May 2022].

World Bank, 2020. *Voice and Accountability.* [Online]
Available at:
https://govdata360.worldbank.org/indicators/he4b8109f?indicator=382&viz=line_chart&years=1996,2020
[Accessed 27 May 2022].

Yann, A., Giorgio, B., Esther, G. & Assenka, H., 2021. *Boosting Social and Economic Resilience in Europe by Investing in Education*, Luxembourg: Publications Office of the European Union.

Appendices

TABLE A1: SPECIES LISTED FOR CORK HARBOUR SPECIAL PROTECTION AREA.

Special Conservation Interests	**Annex 1 Species**	**Baseline Population**	**Population status at baseline**	**National Importance Rank**	**Regional Importance Rank**	**County Importance Rank**
Shelduck (*Tadoma tadoma*)		2,009	All-Ireland Importance	1	1	1
Wigeon (*Anas Penelope*)		1,791	All-Ireland Importance	13	3	2
Teal (*Anas crecca*)		1,065	All-Ireland Importance	8	1	1
Pintail (*Anas acuta*)		57	All-Ireland Importance	7	2	1
Shoveler (*Anas clypeata*)		103	All-Ireland Importance	15	2	2

Red-breasted Merganser (*Mergus serrator*)		121	All-Ireland Importance	6	1	1
Little Grebe (*Tachybaptus ruficollis*)		57	All-Ireland Importance	5	1	1
Great Crested Grebe (*Podiceps cristatus*)		253	All-Ireland Importance	3	1	1
Comorant (*Phalacrocorax carbo*)		521	All-Ireland Importance	1	1	1
Grey Heron (*Ardea cinerea*)		80	All-Ireland Importance	2	1	1
Oystercatcher (*Haematopus ostralegus*)		1,809	All-Ireland Importance	5	1	1

Golden Plover (*Pluvialis apricaria*)		3,342	All-Ireland Importance	14	4	3
Grey Plover (*Pluvialis squatarola*)		95	All-Ireland Importance	19	4	3
Lapwing (*Vanellus vanellus*)		7,569	All-Ireland Importance	5	1	1
Dunlin (*Calidris alpine*)		9,621	All-Ireland Importance	3	1	1
Black-tailed Godwit (*Limosa limosa*)		1,896	International Importance	5	2	2
Bar-tailed Godwit (*Limosa lapponica*)		233	All-Ireland Importance	13	3	2
Curlew (*Numenius arquata*)		2,237	All-Ireland Importance	5	2	2

Redshank (*Tringa totanus*)		2,149	International Importance	2	1	1
Black-headed Gull (*Chroicocephalus ridibundus*)		3,640	All-Ireland Importance	3	1	1
Common Gull (*Larus canus*)		1.562	All-Ireland Importance	3	2	2
Lesser Black-backed Gull (*Larus fuscus*)		783	All-Ireland Importance	2	2	2
Common Tern (*Sterna hirundo*)		102 breeding pairs	All-Ireland Importance	3	1	1
Other conservation designations	SAC	RAMSAR SITE	Important Bird Area (IBA)	Wildfowl Sanctuary	Other	Other

associated with the site[7]	SAC 1058	Yes	Yes	Yes	Proposed National Heritage Areas (pNHA)	

TABLE A2: RATIO OF 2018 GVA OVER AVERAGED GVA OF 2010-2017.

	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Shipping and maritime transport	416.25	433.97	374.59	467.31	488.5	577.56	638.47	670.39	697.21
Marine tourism and leisure	289.52	316.06	329.92	357.49	396.53	433.3	557.54	594.89	648.44
International cruise industry	6.25	7.84	8.86	10.32	9.79	Jan-00	9.76	14.33	20.34
Marine retail services	33.91		34.56	33.37	60.05	68.52	70.96	66.58	74.53
Sea fisheries	65	105.1	142.6	134.7	168.1	114	164.5	166	173
Marine aquaculture	46.2	53.3	60.6	31.19	49.16	81.85	98.4	118.56	100.32
Seafood processing	121.36	140.23	126.71	127.86	135.21	131.41	172.15	179.03	161.13
Oil and Gas exploration and production	25.8	24.89	27.89	26.18	23.96	22.33	71.67	82.26	106.47
Marine manufacturing, construction and engineering	44		32.89	46.72	64.96	65.43	60.98	63.11	67.89

[7] Other designation areas are associated with Cork Harbour but may relate to different areas and some of these designation areas extend outside the SPA boundary.

Advanced Marine Technology products and services	20.81		38.61	43.55	36.11	38.11	60.63	42.66	41.87
Marine commerce	31.81		49.17	49.91	42.17	41.63	41.76	53.17	67.7
Marine biotechnology and bioproducts	12.99		18.76	19.67	4.62	13.91	16.99	26.13	29.77
Marine renewable energy	3.65		8.65	11.95	15.4	18.68	38.1	37.64	37.19
total	**1117.53**	**1081.39**	**1253.75**	**1360.19**	**1494.56**	**1616.86**	**2001.92**	**2114.76**	**2225.85**
Average (2010-2017)								**1505.12**	
Ratio (2018:AVG 2010-2017)									**1.4788521**

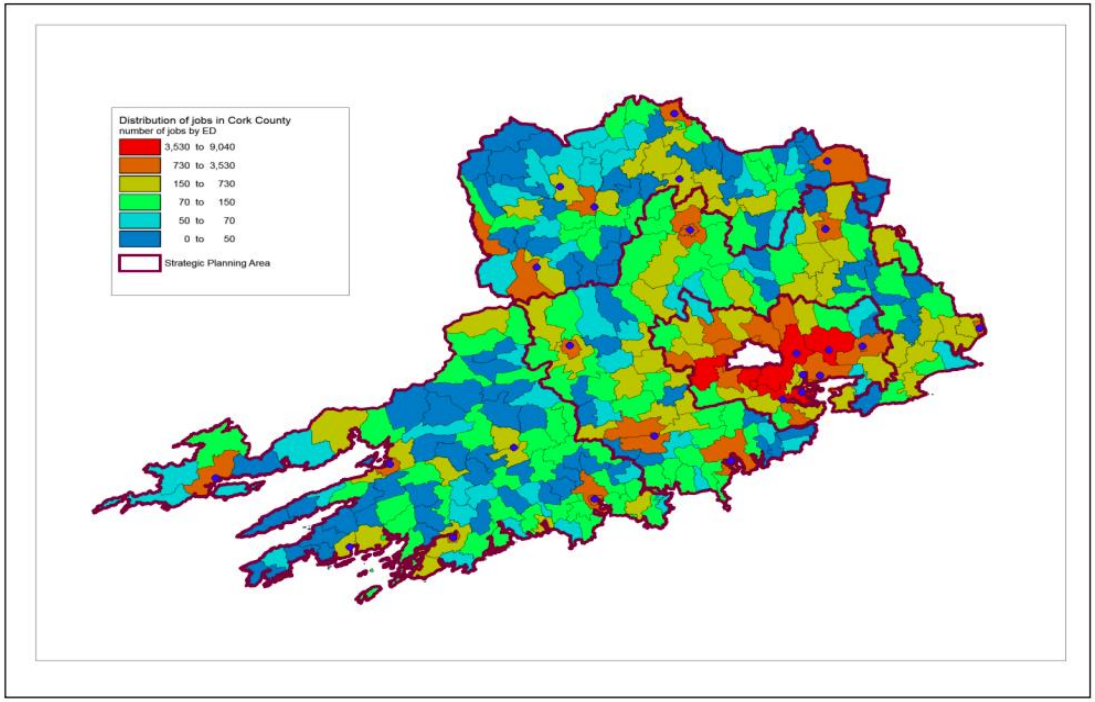

FIGURE A1: DISTRIBUTION OF JOB IN CORK HARBOUR REGION COMPARED TO THE REST OF THE COUNTY (CORK COUNTY COUNCIL, 2019).

TABLE A3: PERCENTAGE BREAKDOWN OF JOBS BY INDUSTRIAL GROUP (CORK COUNTY COUNCIL, 2020).

Industrial Group	**% National Employees**	**% Cork County Jobs**
Agri, Forestry, Fishing	5%	8%
Manufacturing	11%	21%
Build and Construction	5%	4%
Wholesale, Retail, Trade, Transport	23%	26%

Information and Communication	19%	16%
Public Adminstration	5%	3%
Education, Human Health & Social Work activities	20%	17%
Other	4%	4%
Unstated	8%	1%
Total	**1,970,728**	**118,146**

TABLE A4: AQUACULTURE AND FORESHORE MANAGEMENT ACTS.

Fisheries (Amendent) Act, 1997
Marine FinFIsh Licences
Land-based FinFIsh Licences
Shellfish Licences
Foreshore Act 1933
Foreshore Act (Amendment) 1992
Fisheries and Foreshore (Amendement) Act 1998
Fisheries (Amendent) Act, 2003
Maritime Safety Act, 2005
Foyle and Carlingford Act, 2007
Foreshore and Dumping at Sea (Amendment) Act 2009
Foreshore (Amendment) Act 2011
Sea Fisheries Act
Marine Institute Act

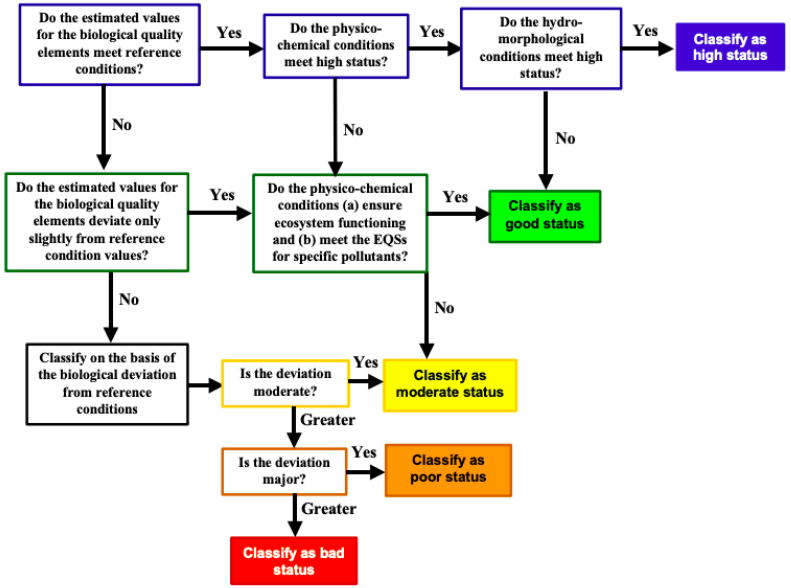

FIGURE A2: WFD CLASSIFICATION SCHEME.

TABLE A5: PUBLIC WATER QUALITY TAKEN FROM THE 10 STATIONS IN THE SYSTEM AREA.

Parameters	**Values from the stations (avg)**	**Parametric (min) values**
Total chlorine (mg/l)	0.493	250
Free chlorine (mg/l)	0.374	250
Coliform Bacteria (MPN/100 mls)	0	0
E.Coli (MPN/100mls)	0	0

Clostridium perfringens (cfu/100mls)	0	0
Ammonium (mg/l)	< 0.026	0.30
Colour (True) (Hazen)	< 5	Acceptable to consumers and no normal changes
pH	8.17	> 6.5 and < 9.5
Conductivity (µS/cm)	170.7	2500
Turbidity (NTU)	0.212	Acceptable to consumers and no normal changes
Aluminium (µg/l)	29.8	200
Iron (µg/l)	< 20	200
Temperature (˚C)	14.01	
Odour (Descriptive)	descriptive	

TABLE A6: WEIGHTED TRANSPORT MODES BY SCORES FOR LITTLE ISLAND, CARRIGTWOHILL AND RINGASKIDDY.

Little Island			
Transport methods	Weight	Percentage	Scores (weight x percentage)
on foot, bicycle, bus, train	5	0.05	0.25
work vehicles	4	0.07	0.28
passsenger in car	3	0.04	0.12
motorcycle	3	0.01	0.02
driving cars	1	0.83	0.83
		Weighted score	**1.5**

Carrigtwohill			
on foot, bicycle, bus, train	5	0.03	0.15
work vehicles	4	0.03	0.12
passsenger in car	3	0.04	0.12
motorcycle	3	0.01	0.03
driving cars	1	0.89	0.89
		Weighted score	**1.31**
Ringaskiddy			
on foot, bicycle, bus, train	5	0.025	0.125
work vehicles	4	0.04	0.16
passsenger in car	3	0.01	0.03
motorcycle	3	0.005	0.015
driving cars	1	0.92	0.92
		Weighted score	**1.25**
		Averaged weighted score	**1.35**