

Adapting to Climate Change on the Coasts of Ireland: Lessons from California

How the Pacific can enlighten the Atlantic?

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Abstract

Coastal areas throughout the world are vulnerable to the effects of a changing climate. The warming of the world's oceans, and the consequent rise in sea levels, will result in more severe coastal flooding, in accelerated erosion, and in the increased occurrence of extreme weather events. The large proportion of the world's population who reside within close proximity of the coast will face serious challenges in dealing with the predicted changes to our coastlines. Due to its location on the periphery of the North Atlantic Ocean, and being a country with a large concentration of development located in coastal areas, Ireland will be exceptionally susceptible to the impacts of climate change. Ireland's ability to adapt to the impacts of climate change in coastal areas is hampered by the lack of a clear national coastal management policy framework, by weaknesses in its adaptation policies, and by a tendency to prefer the use of engineering coastal protection measures. The state of California in the U.S is widely considered a leader in terms of coastal climate change adaptation and it can offer many valuable lessons for Ireland on how Ireland might improve its preparedness for coastal climate risks. Using an in-depth analysis of coastal climate change adaptation planning in both Ireland and California, this thesis will critically examine California's responses to dealing with coastal climate risk and will assess what viable lessons can be used to overcome Ireland's challenges in responding to the impacts of climate change in coastal areas.

Keywords: Climate Change, Adaptation, Coastal Areas

Executive Summary

Introduction

Coastal areas are unique and diverse environments which play a critical role in supporting life on earth. There is a large degree of scientific certainty that the continuing emission of greenhouse gases into the atmosphere has already had, and will continue to have, a negative effect on coastal areas. Greenhouse gases are trapping energy from the sun, and the oceans are absorbing more heat, hence we have an increase in sea surface temperatures and rising sea levels

Climate change will pose major challenges for coastal areas. Therefore, it is of immense importance to devise solutions and to develop tools which will help us to cope with the impacts of climate change. Climate change adaptation which can be defined as an “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities”(IPCC 2001) has emerged as a predominant paradigm on how to prepare for the effects of climate change in coastal areas.

Ireland is an island nation located in the Atlantic Ocean on the edge of the North West of Europe, with a long exposed and populated coastline, and therefore it will be particularly susceptible to the effects of climate change. The state of California, which has been acknowledged as a leader in terms of coastal climate change adaptation, can offer Ireland many valuable lessons on how to overcome the challenges which Ireland faces as it grapples with coastal climate change adaptation.

Research Questions

In order to address why and how California might offer Ireland a number of valuable lessons in relation to coastal climate change adaptation, this thesis will explore the following research questions.

1. In order to understand why Ireland can learn coastal climate change adaptation lessons from California; we need to discover what are the main similarities and differences in terms of physical and soci-economic coastal climate vulnerabilities as well as coastal governance structures?
2. Using the ‘Ladder of Adaptation’ as a framework, what progress has Ireland and California both made in terms of coastal climate change adaptation?
3. What specific lessons from California’s coastal climate change adaptation efforts can assist Ireland to overcome its challenges?

Main Findings

The thesis identifies that there are many similarities and differences between Ireland and California in terms of coastal climate change vulnerabilities. Even though Ireland borders the Atlantic and California borders the Pacific, both coastlines will be vulnerable to the effects of rising seas, increased occurrences of extreme weather events, as well as exacerbated coastal erosion, flooding and storm damage. Despite major differences in population, Ireland and

California have both concentrated their major urban centers and social infrastructure in coastal areas and both economies rely heavily on coastal resources.

In order to evaluate coastal climate change adaptation efforts in Ireland and California, this thesis uses the “The Ladder of Adaptation” as devised by Gurrann et al which outlines what steps need to be taken in order to achieve effective coastal climate change adaptation.

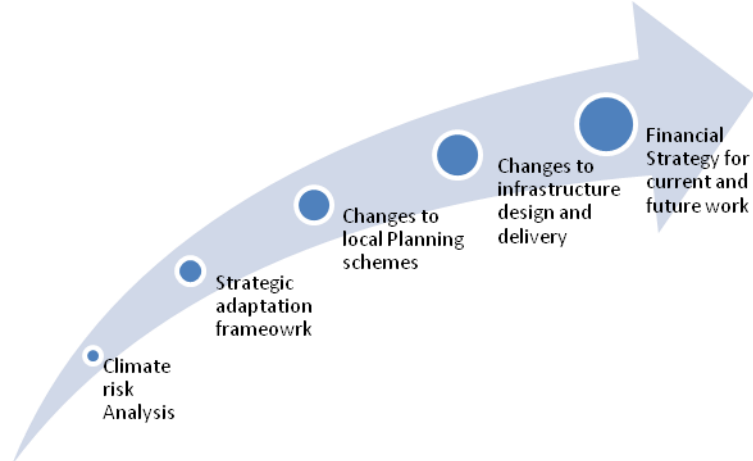


Figure 0-1 *Ladder of Adaptation* (Gurrann et al. 2012)

Using the ladder as a framework, this thesis found that California has made greater progress than Ireland. In comparison to Ireland, California has undertaken a rigorous climate risk analysis and has developed a much more robust adaptation framework. California is also undertaking much more comprehensive updates to local planning schemes. California is also making greater progress than Ireland with regards to adopting more natural coastal protection infrastructure measures as well as financing adaptation activities.

Coastal Climate Change Adaptation Lessons for Ireland from California

1. *Legislation and planning*

When it comes to the legislative and planning aspects of coastal climate change adaptation, California can offer Ireland many important lessons. Unlike Ireland, California has a clear coastal management policy framework. This means that California has been able to integrate its adaptation strategy within the workings of its existing Coastal Act. In addition, Ireland might also learn about the benefits of the localised approach which California has taken; its city and county authorities are involved in developing laws and guidelines to reduce the risk from coastal climate hazards. And also, the fact that California is pursuing an aggressive greenhouse gas emission reduction programme demonstrates to Ireland the need for similar complimentary adaptation and mitigation measures.

2. *Financing Coastal Climate Change Adaptation*

On the question of financing coastal climate change adaptation measures, Ireland can learn about the types of financial activities which it should undertake from the different projects for which California has sourced funding, and how that funding is allocated in California. In addition to providing funding for cities and counties to update their planning processes to accommodate coastal climate risk, state and federal agencies are allocating funding to

undertake educational activities, and are providing funding for the introduction of trial natural coastal protection infrastructure measures, and are also funding expanding public access rights.

3. Natural Coastal Protection Measures

Ireland can learn a great deal from California about the advantages of employing natural coastal protection measures as opposed to relying on hard infrastructure. California has already initiated several wetland, sand dune and salt-marsh restoration projects and other experimental measures which will protect coastal areas against climate risks while also maintaining bio-diversity and public access to the coast. California's two examples of managed retreat (Surfers Point and Pacifica) can help Ireland to understand the advantages of not armoring the coasts and which steps are needed to achieve successful managed retreat.

4. Community Engagement

California's strong emphasis upon community engagement in the coastal adaptation process has resulted in many positive outcomes. Therefore, Ireland can learn a lot from California about the advantages of public participation and the methods used to engage with members of the public. In California, as part of the process of updating local planning processes to include coastal climate risks, city and county authorities are holding meetings, organising workshops and using online platforms to engage with members of the public.

5. Training and Information Provision

Two of the obstacles to effective coastal climate change adaptation in Ireland are: (i) the lack of clear guidelines to assist coastal managers with adaptation and (ii) the lack of detailed monitoring programmes of the Irish coastline. California's state agencies, research institutions and non-profit organisations have developed a wide range of guidance tools and monitoring programmes to support coastal managers with adaptation; as Ireland begins to expand its climate change adaptation efforts, it will be possible to obtain ideas and methodologies from California's tried and tested adaptation support strategies.

6. Multi-stakeholder and regional coordination

Another factor which is impeding the adaptation process in Ireland is that there are many different stakeholders (e.g. ports, roads, energy providers). All of these hold responsibility over coastal resources and there is little formalised integration between them. California has been instrumental in encouraging key stakeholders, whose assets will be at risk to the impacts of climate change, to take part in the adaptation process. As well as integration between different stakeholders, there are examples of city and county authorities along the coastline who are working together to streamline their adaptation efforts.

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Abbreviations

AB	Assembly Bill (U.S)
BAECCA	Bay Area Ecosystems Climate Change Consortium (U.S)
BCDC	San Francisco Bay Conservation and Development Commission
CAKE	Climate Adaptation Knowledge Exchange
CAL-TRANS	Californian Department of Transportation
CAS	California Adaptation Strategy
CCC	California Coastal Commission
CCSF	City and County of San Francisco
CEC	California Energy Commission
CMRC	Coastal and Marine Research Centre (Ireland)
C-SMART	Collaboration: Sea-Level Marine Adaptation Response Team
CNRC	California Natural Resources Agency
COS	Centre for Ocean Solutions (U.S)
EPA	Environmental Protection Agency (Ireland and U.S)
FEMA	Federal Emergency Management Agency
FWS	U.S Fish and Wildlife Service
GHGs	Green House Gas Emissions
ICARUS	Irish Climate Analysis and Research Unit
ICLEI	Local Governments for Sustainability
ICZM	Integrated Coastal Zone Management
IPCC	Intergovernmental Panel on Climate Change
LCP	Local Coastal Program (U.S)
MBNMS	Monterey Bay National Marine Sanctuary
MSPD	Marine Spatial Planning Directive (E.U)
NCCAF	National Climate Change Adaptation Framework (Ireland)
NOAA	National Ocean and Atmospheric Administration
NRC	National Research Council
OPC	Ocean Protection Council (U.S)
OPW	Office of Public Works (Ireland)
PPIC	The Public Policy Institute of California
USGS	United States Geological Survey
SCC	California Coastal Conservancy
SLR	Sea Level Rise
SPUR	San Francisco Planning and Urban Research Association

1 Introduction

The world's coasts and oceans play a crucial role in supporting life on Earth. Coastal areas, situated, as they are, at the interface between the marine and terrestrial environment, are the most diverse and dynamic environments in the world. Human induced climate change has already posed, and will continue to pose, many challenges for the world's oceans and coasts. Greenhouse Gas Emissions (GHGs) are causing heat to be trapped in the oceans and in the atmosphere and this is contributing significantly to the thermal expansion of the oceans and the melting of land-based ice (IPCC 2013). Consequently sea levels are rising and the occurrence of extreme weather events is increasing; this is leading to exacerbated erosion, flooding, inundations and the loss of important ecosystems (Nicholls 2011).

As a society, we have settled en-masse in coastal areas throughout the world. According to the United Nations, almost 44% of the world's population lives within 150km of the coasts (2010). The primary motivation for our need to live in coastal areas is based on economic factors; this is due to the plethora of industries which rely on coastal resources including transportation/shipping, trade, mariculture, agriculture, the development/exploitation of natural resources, and tourism (United Nations 2010). People also have a strong desire to live near the sea so that they may avail of inspiring sea and ocean views, fresh sea air, and make use of the beaches. However, our dependency on coastal resources has meant that we have put ourselves in an increasingly vulnerable situation due to the predicted impacts of climate change. Rising seas and increased storm activity will threaten to harm our expansive coastal built environment and infrastructure. The decision to build so close to the coast, coupled with the now emerging need to build coastal protective infrastructures to ensure the safety of various developments, will have negative impacts on our natural coastal ecological systems; for example man-made barriers will hinder the natural migration patterns of these ecological systems (Nicholls 2011).

The fact that such a large proportion of our society bases their lives around coastal areas poses numerous challenges in the face of climate change. Sea Level Rise (SLR) along with more extreme weather events and the consequential flooding will cause serious damage to settlements and infrastructure situated in coastal areas (IPCC 2013). As a society, it is of great importance that we develop policies and mechanisms and act collectively to confront the challenges associated with climate change in coastal areas. One of the most prominent paradigms to emerge on how to confront climate change issues in coastal areas is 'adaptation'. Adaptation is a process which involves making adjustments that are reactive or anticipatory to reduce the vulnerabilities to climate change.

As an island nation, situated in the North West Atlantic Ocean, Ireland's coastline and coastal communities will be highly vulnerable to the effects of climate change. A snap shot of these vulnerabilities was displayed in the serious winter storms of late 2013 and early 2014. Coastal areas were the worst hit by these storms. In addition to the widespread disruption to essential services, it was estimated that, over an eight week period, the destruction of infrastructure and flooding damage cost the country an estimated €110 million (Department of Environment, Community and Local Government 2014). Therefore, it is of the utmost importance for Ireland to undertake a rigorous programme of coastal climate change adaptation. A year before these very severe storms, at the end of 2012, the Irish government, with a view to reducing Ireland's vulnerability to climate change, launched its National Climate Change Adaptation Framework (NCCAF 2012). This framework provides a strategic policy focus to

ensure adaptation measures are taken across different sectors and levels of government. The NCCAF does not adequately addressing the severity of coastal climate risks. Furthermore, coastal climate change adaptation in Ireland has also been hampered by weaknesses in coastal governance. Due to the severity of the threats relating to climate change in coastal areas in Ireland, there is a major need to improve Ireland's adaptation efforts.

Even though it is located in a completely different geographical location, the state of California in the U.S. can offer Ireland many valuable lessons regarding coastal climate change adaptation. California is widely regarded as a leader in terms of coastal climate change adaptation (Moser and Boykoff 2013). California has developed a rigorous adaptation strategy and coastal communities are actively identifying risks, devising and implementing adaptation options with support from state and scientific agencies (CNRA 2013). Therefore, this thesis will identify and assess to what extent elements of California's adaptation efforts can help to overcome the challenges which face Ireland.

1.1 Problem definition

Ireland's long exposed coastline is highly vulnerable to the impacts of climate change. In Ireland, major cities and towns, social infrastructure and other important economic interests are located in coastal areas. Recent storms and flooding gave a clear indication of the type of extreme weather events which Ireland's coasts are predicted to experience in relation to climate change. Unfortunately, coastal management in Ireland is highly fragmented, and there is a preference for hard infrastructure coastal protection measures over more natural ones; there is a lack of coastal monitoring data and the National Adaptation Framework, although little over two years in existence, has yet to contribute to any meaningful adaptation. On a positive note, the severity of the recent storms managed to draw attention to the coastal climate change adaptation issues and created an appetite for change.

There is a large degree of evidence that California has achieved a head start in terms of coastal climate change adaptation and this thesis will explore to what extent California's adaptation efforts can assist Ireland in overcoming its problems (Moser and Boykoff 2013, Georgetown Climate Centre 2015).

1.2 Research questions

In order to understand why California is an appropriate case to assist Ireland in its coastal climate change adaptation efforts and what specific lessons Ireland can learn from California, this thesis will examine the following research questions;

1. In order to understand why Ireland can learn coastal climate change adaptation lessons from California, what are the main similarities and differences in terms of physical and socio-economic coastal climate vulnerabilities as well as coastal governance structures?
2. Using the 'Ladder of Adaptation' as framework, what progress has Ireland and California made in terms of coastal climate change adaptation?
3. What specific lessons from California's coastal climate change adaptation efforts so far can assist Ireland overcome its challenges

1.3 Methods

For the purpose of the thesis, three primary methods were employed to justify why California can provide lessons for Ireland, as Ireland begins to undertake its coastal climate change adaptation efforts.

1. Literature Review

An extensive literature review was undertaken to firstly comprehend the primary physical and socio-economic risks related to the impacts of climate change in coastal areas and to examine other material related to the most prominent discourses on how best to prepare for the impacts of climate change in coastal areas. Resources such as academic journals, coastal climate change physical and socio-economic vulnerability assessments, government reports, local planning documents, official website and newspaper articles were used to evaluate coastal climate change adaptation efforts in Ireland and California.

2. Interviews

In order to develop (i) a clear understanding and (ii) to discover the most up to date information regarding coastal climate change vulnerabilities and adaptation efforts in both Ireland and California, semi-structured interviews were conducted with researchers and officials working in the area of coastal climate change adaptation. The purpose each interview in Ireland was to understand the weaknesses of coastal climate change adaptation in Ireland and to identify specific areas in which Ireland had scope for and could implement improvements. On the other hand, the goal of the interviews in California was to try and identify the strengths and weaknesses of their coastal climate change adaptation efforts and identify elements which would be replicable in Ireland. Due to the very significant amount of activity taking place in California, the interviews helped in giving a focus to the vast amount of information available and in pointing out best management practices related to coastal climate change adaptation. A full list of the interview participants and organisations may be found in Annex 1.

3. Analytical Framework

There is a growing recognition that in order to have successful adaptation planning, decision making should follow a core set of principles. Therefore, in order to evaluate coastal climate change adaptation efforts in Ireland and California in a structured manner, this thesis employs the 'Ladder of Adaptation' as devised by Gurran et al. This 'Ladder of Adaptation' device was used by Nicole Gurran, of the University of Sydney, and others, when examining climate change adaptation in coastal Australia (2012). The study revealed a ladder of adaptation action "whereby communities tend to accomplish early steps before they move on to more complex expensive, or political policies" (Gurran et al 2012, 1). The ladder of adaptation was chosen as an analytical framework because it clearly outlines the steps which need to be undertaken in order to achieve effective coastal climate change adaptation. Furthermore, the Ladder of Adaptation in many ways reflected the coastal climate change adaptation processes already in existence in Ireland and California; therefore it was felt that it would be a useful method of evaluating what was happening with coastal climate change

adaptation in Ireland and California. Figure 1-1 outlines the steps on the ladder of adaptation and what each step entails;

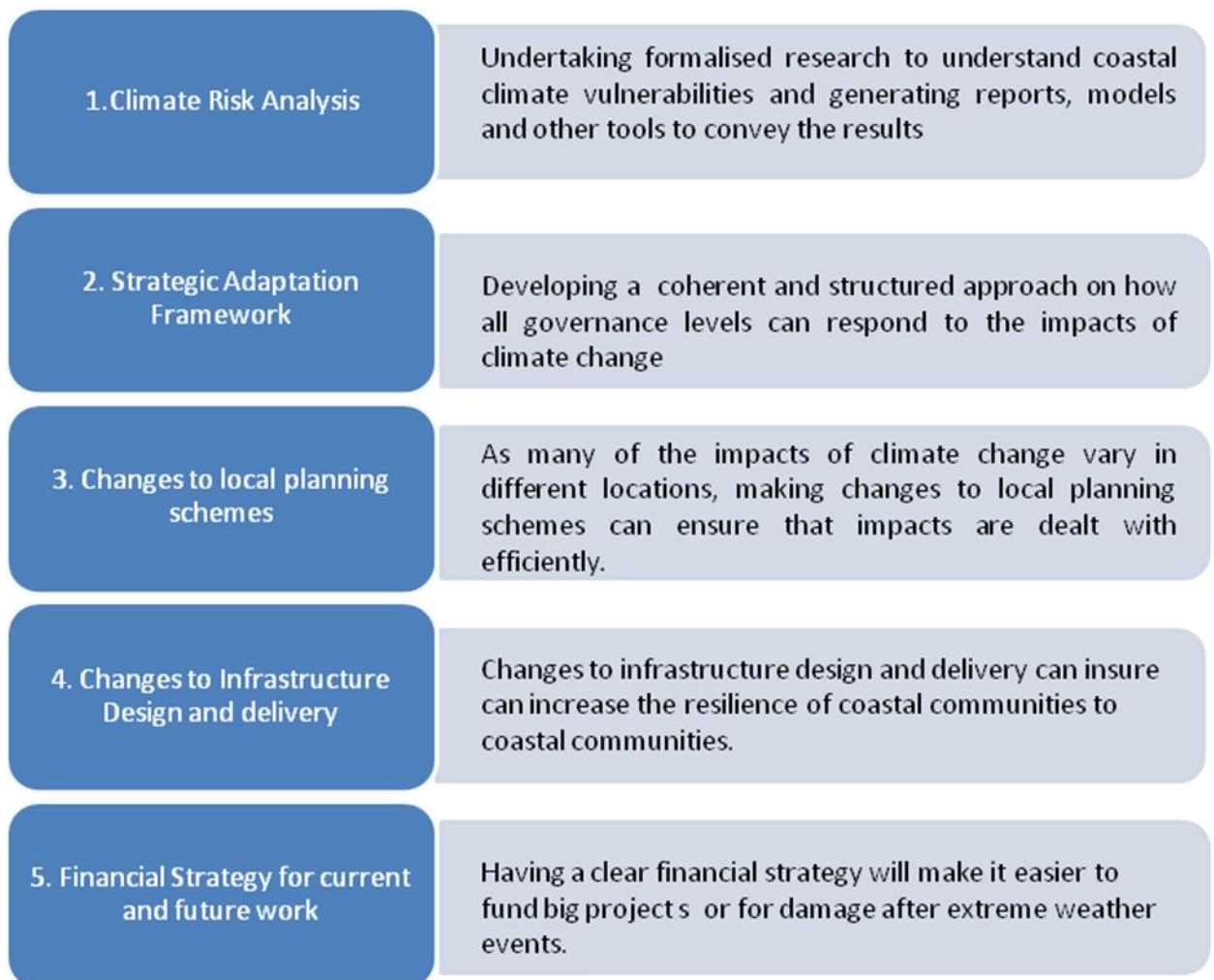


Figure 1-1: Ladder of Adaptation (Gurran et al. 2012)

Finally, I brought all of this information together to identify key lessons from California's adaptation efforts in the expectation that these lessons will enable Ireland to deal with the various physical, socioeconomic and governance challenges posed by climate change and that the information will assist Ireland with its coastal climate change adaptation efforts. I organized the lessons in the following distinct themes; (1) Legislative and Planning, (2) Financing Coastal Climate Change Adaptation, (3) Natural Coastal Protection Measures, (4) Community Engagement, (5) Training and Information Provision, and (6) Multi-stakeholder and Regional Integration co-ordination.

1.4 Limitations and scope

There are a number of limitations which have influenced the outcomes of this study. One of the primary limitations with this thesis is that coastal climate change adaptation is a rapidly evolving subject and this makes it difficult to assess at this stage what are best practices in the field. Even though California has made significant progress with coastal climate change adaptation, a lot of the work which is being carried out is still in the vulnerability assessment and assessing adaptation options stage.

Another limitation is that there is still a certain amount of uncertainty in relation to the effects of climate change on coastal areas and this makes it challenging to identify the most effective geo-physical adaptation measures.

While this thesis points out there are many similarities between Ireland and California in terms of physical and socio-economic vulnerabilities, it is also important to highlight that there are many major differences. There are many political and cultural differences between Ireland and California. California is a state and Ireland is a county and there are many differences in how their political systems operate. For that reason, coastal climate change adaptation efforts in California should not be perceived as a model for Ireland, but rather as lessons which might be beneficial for Ireland. In line with the concept of adaptive management, ideas generated in California could be piloted in Ireland and monitored closely in order to evaluate their relevance, applicability and adaptability.

1.5 Audience

The thesis intends to reach a broad range of actors on the European coasts of the Atlantic and on the Canadian/United States coasts of the Pacific. In Ireland, the thesis will be of use to policy makers at multiple levels of government including at E.U. level, national level and local government level, and specifically to those who play an important role in preparing the Irish coasts for the impact of climate change. Environmental lobby groups in Ireland who wish to lobby for change in coastal policy in Ireland should also find this thesis of interest. Concerned citizens living in coastal areas in Ireland, and who are at risk to the hazards associated with climate change, will find this thesis useful; it will give them a clear understanding of the risks and encourage them to engage in conversation and debate about coastal adaptation measures.

As this thesis also provides a critical analysis of coastal climate change adaptive measures in California, it will be useful in highlighting areas both where California is excelling and is lagging behind in terms of coastal climate change adaptation. This thesis will also help key stakeholders in California assess which elements from their adaptation efforts could be transferable both nationally and internationally.

1.6 Disposition

The Structure of this thesis is as follows:

- Chapter 2: The second chapter will briefly outline the main physical and socio-economic impacts related to climate change in coastal areas on a global scale. It will also introduce the concept of climate change adaptation and how it can be useful in dealing with coastal climate risk. The chapter will also outline specific coastal climate change adaptation measures and consider their usefulness.
- Chapter 3: The third chapter gives an overview of the main physical and socio-economic challenges which coastal areas in Ireland will face. It will also evaluate Ireland's coastal governance system and its ability to deal with climate change issue. The ladder of adaptation will be used to evaluate Ireland's progress in terms of coastal climate change adaptation.
- Chapter 4: In order to justify why California can assist Ireland with its coastal climate change adaptation efforts , the fourth chapter will also provide an overview of the principle impacts of climate change in coastal areas of California and also assess their coastal governance system. The ladder of adaptation will be used to analyse California's coastal adaptation efforts. This chapter will conclude with a table which ranks Ireland's and California's progress in terms of coastal climate change adaptation will help to identify which areas in particular where Ireland can learn from California.
- Chapter 5: This chapter will identify and justify the specific lessons from California which could be useful for Ireland and categorize them into the following themes; (1) Legislation and Planning (2) Financing Coastal Climate Change Adaptation (3) Natural Coastal Protection Measure (4) Community Engagement (5) Training and Information Provision (6) Stakeholder Integration and Regional Co-ordination
- Chapter 6: This chapter will look at other less apparent elements of California's coastal climate change adaptation efforts which could be useful for Ireland and identify the many opportunities which the impacts of climate change can offer coastal areas in Ireland.
- Chapter 7: The final chapter will summarize the main findings of this thesis and also point out areas for further research.

2 Impacts and Responses to Coastal Climate Change on Global Level

2.1 Physical Vulnerabilities of Climate Change in Coastal Areas

There is a large degree of scientific consensus that the continuing emission of greenhouse gases is trapping heat in the atmosphere and is causing the warming of air and sea temperatures, and is also causing the world's oceans to acidify through the carbon dioxide they absorb (IPCC 2013). Even if the emission of greenhouse gasses was to halt today, the temperatures of the air and sea will continued to rise due to past emissions (Nicholls 2011). The absorption of additional heat energy by the surface of the earth is causing sea surface temperatures to rise exponentially (Nicholls 2011). Global mean sea level is rising due to the thermal expansion of seawater and the melting of land based ice. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) showed that global average sea level rose at average rate of 2.0mm per year from 1971 to 2010 (2013). The rate increased from 1993 to 2010 where the average rate was 3.2mm per year (IPCC 2013). It is also predicted that climate change will lead to increases in extreme wave heights and in the intensity of storms (IPCC 2013). It is very important to point out that coastal areas are complex socio-ecological systems. The increase in sea level rise and extreme weather events will not be uniform and there will be strong regional variations depending on topography and location (IPCC 2007).

Changes in sea surface temperatures and resulting increases in sea level rise, along with more extreme weather events, will contribute to noticeable changes in coastal areas. Sea level rise will lead to increased shoreline erosion rates and the migration of coastal habitats inland (Nicholls 2011). Sea level rise also has the potential to damage beaches, rocky shores and cliffed coasts (Nicholls 2011). Many of the world's most sensitive ecosystems such as coral reefs, salt marshes and wetlands are located in coastal areas (United Nations 2010). Coastal areas are also home to a rich array of bio-diversity; 80% of the world's 13,200 known species of marine fish can be found in coastal areas (United Nations 2010) Climate change will threaten the future viability of sensitive coastal ecosystems. Further information on how climate change will affect coastal areas can be found in figure 2-1.

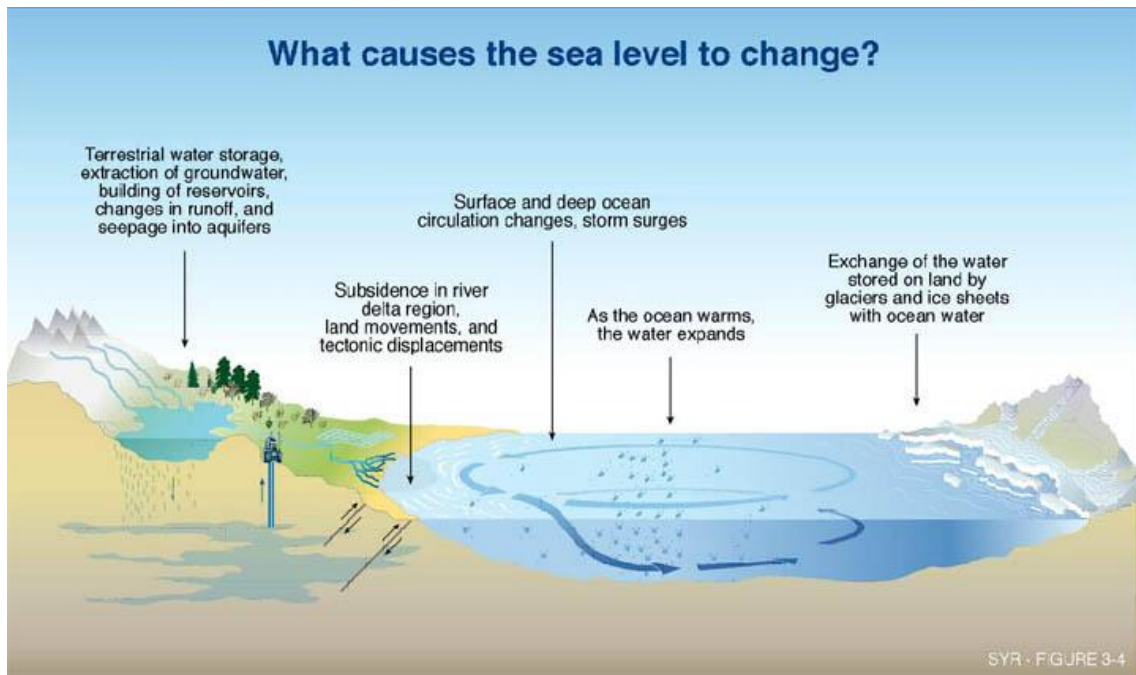


Figure 2-1: *Causes of Sea Level Change (IPCC 2001)*

2.2 Socio-economic Vulnerabilities of Climate Change in Coastal Areas

As well as natural environments, human populations will also be threatened by a combination of warming air and water temperatures, rising sea levels, and changes in storm and rainfall patterns. Approximately 2.7 billion people live in coastal areas and eight out of the world's ten largest cities are located on the coast (United Nations 2010). Even putting climate change issues aside, coastal areas are vulnerable to a variety of serious challenges including population growth, water pollution, habitat change, and resource exploitation and degradation (United Nations 2010). Climate change will exacerbate the impacts of these problems for coastal communities.

The combination of Sea Level Rise (SLR) and the occurrence of more extreme weather events will lead to greater incidence of coastal flooding and inundation. This will contribute to significant damage to buildings and infrastructure and, in some cases, force coastal communities to relocate inland. Coastal areas are also home to some of the world's most important economic sectors including mariculture, shipping, tourism and wide variety of other industries (United Nations 2010). Climate change means that the future viability of these sectors and the livelihoods of millions of people are at severe risk of rapid decline.

2.3 Climate Change Adaptation Measures in Coastal Areas

Due to the severity of the physical and socio-economic impacts associated with climate change in coastal areas, there is a growing realization that society must act to adequately address the effects. Climate change mitigation which generally involves undertaking aggressive policies to reduce greenhouse gas emissions can slow the rate of SLR. However, with a growing realization that successful and sufficient climate change mitigation is almost impossible, adaptation has emerged as a prominent discourse on how society can respond to

changing climatic conditions, while not ignoring mitigation measures. The Inter-government Panel on Climate Change defines climate adaptation as “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities” (2007).

A more comprehensive definition of climate change adaptation by David and Chornesky is “a set of interrelated activities that include engaging and motivating stakeholders across sectors and social institutions; providing best available data, information, tools, and guidance to inform actions at multiple scales and jurisdictional levels; producing coherent strategies and priorities for adaptation actions; procuring new or redirecting existing funds to achieve meaningful adaptation; and implementing adaptation strategies through new infrastructure, policy, and management actions and reforms (including monitoring and evaluation)”(2014,2)

Adaptation to climate change is not a new phenomenon. Environmental changes throughout history have forced human societies to alter their relationship with nature, whether by migrating to a new area, modifying our shelters or changing the produce we cultivate. However, the effects of climate change are nowadays occurring at a much faster rate and the effects from one part of the world have the potential to have repercussions throughout the world. Therefore, governments and society from different nations all need to implement climate change adaptation in a timely, integrated and structured manner. Due to the wide range of regional, physical and socio-economic impacts on political cultures affected by climate change, there is no one size fits all solution on how to implement climate change adaptation. Climate change adaptation is a concept which is constantly evolving and there are many schools of thought as to how it can be implemented.

Due to the large amount of complexities related to climate change and the evolving nature of adaptation, an ‘adaptive management’ approach can be useful in dealing with climate change issues. An adaptive management approach recognizes that scientific information about environmental systems is incomplete (US AID 2009). In order to deal with uncertainties, an emphasis should be placed upon learning through experimentation and monitoring and make adaptive management decisions based on what is learned (US AID 2009). The paradigm of ‘resilience’ whereby “social ecological systems absorb disturbances while retaining the same basic structures” is also gaining prominence in the sphere of climate change adaptation (IPCC 2007).

Dealing specifically with coastal areas, a wide variety of climate change adaptation measures have emerged. Traditionally, a major emphasis was placed upon engineering responses to protect against coastal flooding and erosion; these responses included the construction of sea-walls, levee, and rock armoring (Cooper and Pile 2013). Nowadays, there has been a shift towards more precautionary adaptation options in coastal areas including zoning, land use regulation, retrofitting buildings, green infrastructure, natural coastal habitat restoration, warning systems and flood damage insurance(US AID 2013). A more detailed assessment outlining the major coastal climate change adaptation options and their advantages and disadvantages can be found in Table 2-2.

Coastal Adaptation Options	Details
Engineering Options	Examples include the construction of sea walls, flood barriers, dykes, levees or beach nourishment. Helpful for minimising the effects of coastal changes on existing coastal communities. Expensive to construct and maintain, may have to be updated in future, encourages development in coastal areas and gives people a false sense of security, prevents coastal ecosystems from moving inland and leads to their demise.
Managed Retreat	Involves the deconstruction or realigning of engineered structures to allow the reoccupation of former intertidal areas and retreat of shoreline landwards. Protects coastal ecosystems habitats and wet/marsh lands can act as coastal protection measures. Cost effectiveness depends on location. Easier to undertake in open coasts as opposed to developed ones.
Changing Construction Styles	Can involve the construction of floodable basements, raising buildings, use of flood resistant materials and other retrofitting measures. Can be enforced with strict building standards. Difficulty in convincing building owners to participate and challenging with older properties
Early Warning/Evacuation Planning	When it is not possible to eliminate the risks from flooding or coastline recession, strategies can be put in place consisting of warning systems, evacuation routes, emergency procedures and provision of sheltered accommodation.
Avoid Development in at risk areas	Implementing strict planning controls preventing development in areas which will be vulnerable to the impacts of climate change.

Table 2-1 Coastal Adaptation Options (Cooper and Pile 2013)

The concept of Integrated Coastal Zone Management (ICZM) has also emerged as a major paradigm on how to adapt to climate change in coastal areas. ICZM can be defined as “an iterative and evolutionary process for achieving sustainable development by developing and implementing a continuous management capability that can respond to changing conditions, including the effects of climate change”(Bijlsma et al. 1996,310). ICZM places a major emphasis on enhancing adaptive capacity which is vital to deal with the adverse impacts of climate change (Shaw et al. 2010). ICZM also requires strong community participation in planning and implementation, which is also very important for adaptation to climate, issues (Shaw et al. 2010). The European Union and the IPCC have welcomed ICZM as a mechanism to support coastal climate change adaptation (European Commission 2015a, Moksness et al. 2009)

Despite the many opportunities associated with coastal climate change adaptation, there are also many challenges. Uncertainties about the impact of climate change in coastal areas make it difficult to assess which adaptation actions will be the most beneficial. The broad definition of adaptation makes it difficult to understand what effective coastal climate change adaptation should consist of. In many parts of the world, a lack of financial, human and technological resources place limits on the amount of adaptation actions which can take place (Nicholls 2011). There are also many difficulties in getting coastal communities and policy makers to support adaptive measures. Acceptance to adaptation measures is most challenging among coastal communities who have strong cultural or economic connections to the sea and to the coast and who feel that adaptation measures may threaten their traditional relationships with sea and ocean life. (Nicholls 2011). Timing is also a major issue of contention in the

implementation of climate change adaptation; some would argue that the impacts will not be felt for a long time and that adaptation measures should wait, while others argue that climate change adaptation is not happening quickly enough (Nicholls 2011).

3 Ireland

3.1 Physical Vulnerabilities of Climate Change in Irish Coastal Areas

As an island nation situated in the North-East Atlantic Region, Ireland's coasts are particularly vulnerable to the impacts of climate change. Ireland's coastline is approximately 4,577km long and borders the Atlantic Ocean on the west and the Irish Sea on the east (Devoy 2008). The coasts of Ireland are characterised by a mixed topography. The Atlantic coast consists of a high relief of rock cliffs separated by bays and inlets. The west coast receives the full force of North Atlantic storms (Cooper 2013). On the other hand, the east coast is predominantly low-lying and only receives about 20% of the wave energy from the Atlantic but is more susceptible to coastal erosion (Cooper 2013).

Even putting climate change issues aside, erosion and coastal flooding has always had a negative impact on the Irish coast. Twenty percent of the Irish coastline is actively eroding but with notable regional variations (Devoy 2008). Sections of the east coast are especially vulnerable, with a maximum erosion rate of 2 meters per annum in some areas, while other more sheltered areas have an erosion rate of almost zero (Devoy 2008). The low-lying lands, bays and estuaries on the Irish coastline are prone to flooding during times of high tides, storm surges and heavy precipitation (Devoy 2008). Climate change will accelerate the rate of erosion and coastal flooding on the Irish coast.

Sea levels have been rising along Ireland's coastline over the last century, and the rate at which the levels have been rising is expected to augment over the next century. The predicted increases in sea level will result in the inundation of many coastal areas in Ireland (Flood and Sweeney 2012). A 0.5 meter rise in sea level is estimated to inundate 200km² of land area in Ireland. Increases in sea surface temperatures will lead to more intense cyclones and increase the amount of storm surges on the Irish coasts (Flood and Sweeney 2012). Models have predicted that storm surge heights could increase by 50-100 cm and also increase in frequency along the Irish coastline. There has also been an increase in severe coastal storms over the last twenty years and give an indication of what the conditions will be like in future. Severe cases of coastal storms and flooding in Ireland took place in 2002, 2009, 2013-2014 (Met Eireann 2015). Figure 3-1 illustrates the extent of damage caused by coastal flooding in Ireland following the serious storms of 2013-2014 in the seaside town of Lahinch in County Clare.



Figure 3-1: Coastal Flooding in Lahinch, County Clare during Winter Storms 2013-2014 (Irish Examiner 2014)

Climate change will also put major pressure on the unique natural environment of the Irish coast. Rising sea levels will have the potential to inundate the salt marshes and sand dunes which are home to important native species, and we must remember that these salt marshes and sand dunes also act as natural coastal protection devices (Climate Ireland 2014). Saltwater intrusion from rising seas may also harm Ireland's ground water supplies. Ireland's groundwater supplies will be of greater importance in the future as the projected decreases in summer rainfall will result in a greater dependence on groundwater supply (Climate Ireland 2014).

3.2 Socio-economic Vulnerabilities of climate change in Irish coastal Areas

The physical risks associated with climate change will also have a negative impact on the population and economy of the Irish coasts. Approximately one third of Ireland's total population lives within 5km of the coastline (Devoy 2008). Most of the population is centred in and around the major coastal cities including Dublin, Cork, Limerick and Galway (Cooper 2013). During the 'Celtic Tiger' period of unprecedented economic growth, there was a substantial increase in coastal development, particularly second homes and holiday homes (Cooper 2013). In terms of socio-economic class backgrounds, there are a mixture of both upper classes and lower classes living in coastal areas. All of Ireland's coastal communities will be susceptible to changing sea conditions associated with climate change.

A large proportion of Ireland's essential infrastructure including ports, roads, the rail network, power plants, schools and hospitals are situated in coastal areas and these will be vulnerable to the effects of climate change (Devoy 2008). Many of Ireland's key economic sectors are also based in coastal areas including fishing, tourism, agriculture and transport (Devoy 2008). A study by Morrissey et al. found that Ireland's coastal economy is worth €1.44 billion, with approximately 17,000 people employed in the marine sector alone (2011).

Research by Devoy, looking at the potential impact of a one-meter SLR by the end of the century finds that 250,000 people would be affected by coastal impacts, 100,000 people would be at risk from SLR induced flooding and there would be capital losses of €135 million related to agricultural land (2008). Another economic vulnerability analysis conducted by Richards and Nicholls found that a high SLR of 58.5cm could lead to €224 millions euros worth of damage with no adaptive management practices in place (2009). The greater amount of population, infrastructure and economic activity concentrated on the coast will all be at risk to any future climatic changes.

It is clearly obvious that Ireland faces many serious challenges associated with the physical and socio-economic impacts of climate change in coastal areas and a comprehensive programme of adaptation measures is needed to prepare for these threats.

3.3 Coastal Governance in Ireland

As was previously mentioned, strong coastal governance will assist effective coastal climate change adaptation. In terms of coastal governance in Ireland, there is a large amount of evidence to suggest that there are many strengths and weaknesses. One of the major barriers for effective coastal governance is that Ireland does not have an over-arching coastal policy and responsibility for coastal resources is highly fragmented (O'Hagan and Ballinger 2010). In fact there is a wide variety of statutory bodies responsible for the planning and management of Ireland's coastal environment (Falaleeva et al. 2011). Ireland's coastline is administered by range of policy and planning instruments, such as local development plans, departmental regulations (e.g. infrastructure, energy, agriculture) as well as national and international development and environmental policies (O'Mahony et al 2014). There is no formalised co-operation between marine and terrestrial planning in Ireland which makes it difficult to make decision on issues related to Ireland's changing coastline (O'Mahony et al 2014). A study by O'Mahony et al. found that governance of coastal issues is spread across six government departments and over 17 organisations with little formal integration taking place between them.

Unlike other European Union member states, the absence of Integrated Coastal Zone Management Policy legislation in Ireland has to be perceived as a major obstacle for dealing with coastal climate change issues. A draft coastal zone management policy was published in 1998 and suggests the use of ICZM, alongside other measures, would overcome institutional barriers pertaining to coastal management in Ireland (O'Mahony et al 2014). However despite the publication of the draft policy, it was never officially adopted by the central government. Despite the fact there is no legislative requirement for ICZM in Ireland, there have been initiatives taken on a regional level. Cork harbour has developed an Integrated Management Strategy and Bantry Bay has completed a project using ICZM principles (O'Mahony et al. 2014). Counties on the east coast such as Wicklow and Wexford have included guidelines related to ICZM in their latest county development plans (Flood and Schechtman 2014). As stated previously, there is clear link between coastal climate change adaptation and ICZM; Ireland reluctance to implement ICZM will act as further constraint for coastal climate change adaptation in Ireland.

As a result of not having a strategic coastal management policy, one cannot be assured that Ireland's coasts are managed in a way which will adequately equip them for dealing with the coastal climate change issues. Traditionally, a large proportion of the responsibility for dealing with coastal issues falls into the hands of the local authorities (O'Connor et al. 2009).

This proved to be advantageous because it allowed local coastal officials to identify and promptly deal with coastal issues without having to consult central government (O'Connor et al. 2009). However, the lack of clear coastal management policy meant that sometimes local authorities undertook coastal protection works which may have suited the interests of the local community as opposed to the examining the wider environmental benefits of the project (O'Connor et al. 2009). In many local authorities, the role of a coastal manager was often undertaken by an environmental or road engineer, who may not have had the appropriate coastal management training or capabilities for implementing effective coastal protection and climate change adaptation strategies (O'Connor et al. 2009). However, the recent transfer of responsibilities for dealing with coastal protection and flooding to the national Office of Public Works should ensure a more consistent approach to coastal protection in Ireland (Flood and Schechtman 2014).

It is important to point out that Ireland's membership of the European Union may assist with improving the effectiveness of coastal governance in Ireland. As part of the Marine Strategy Framework Directive (MSFD), EU member states are required to use an integrated approach to achieve 'a good environmental status' of marine water by 2020(2014). The fact that the MSPD calls for coherency between terrestrial and marine spatial planning may help to overcome the fragmented nature of coastal management in Ireland (MSFD 2014).

The weaknesses of coastal governance in Ireland are acting as a major barrier for effective coastal climate change adaptation in Ireland and thus it is of great importance for Ireland to improve the manner of which it manages coastal areas.

3.4 Coastal Climate Change Adaptation in Ireland

In order to evaluate the progress of coastal climate change adaptation in Ireland and to identify lessons which Ireland might learn from California, this section will use the 'Ladder of Adaptation' as devised by Gurrann et al as a framework.

1. Climate Risk Analysis/ Research

In terms of coastal climate risk analysis, it is clear that Ireland has made a certain degree of progress. The Environmental Protection Agency (EPA) has produced a report entitled "Current and Future Vulnerabilities to Climate Change" (2013). This report gives a broad overview of the main risks which Ireland will face, including those in coastal areas. Dealing specifically with coastal issues, a short risk analysis on Climate Change Impacts was undertaken by the chief engineer of the Department of Communications, Marine and Natural Resources (Farrell 2007). And a study carried out by Flood and Sweeney, from the Irish Climate Analysis and Research Units (ICARUS), quantified the main impacts of potential Sea Level Rise scenarios in Irish coastal cities (2012). Another study by Devoy from University College Cork examined the main physical and social-economic consequences of Sea Level Rise in Ireland (2008). As part of the Irish Coastal Protection Strategy Study (ICPSS), the OPW completed detailed maps assessing the risk of SLR on the Irish coastline (2013).

In addition to the formalised risk analysis, there is a significant amount of research by various research institutions which seeks to understand coastal climate hazards. The Coastal and Marine Research Centre CMRC/Beaufort Institute has been involved in numerous initiatives and projects related to coastal climate change adaptation, including monitoring and mapping of coastal hazards as well as studies related to coastal governance. The CMRC, in conjunction

with the Irish Environmental Protection Agency (E.P.A), has also overseen the development of an online tool called the Climate Information Platform whereby decision makers and stakeholders can access information regarding climate impacts, vulnerability and adaptation options(Falaleeva et al. 2013).

One of the major obstacles for adequate coastal climate change adaptation in Ireland is the lack of long term and detailed monitoring programme of changes to the Irish coastline (Falaleeva et al. 2013). This lack of monitoring data makes it difficult to identify which areas of the Irish coastline will be most vulnerable to the impacts of climate change; and hence difficult to identify the most suitable adaptation options. The National University of Ireland Galway in collaboration with the OPW has recently commenced a long term monitoring programme in West Kerry on how to devise coastal management strategies for coping with future coastal climate risks (2015). Ireland's National Metrological Service (Met Éireann) is also actively monitoring coastal weather conditions on the Irish coastline and has devised a comprehensive warning system for high tides, storm surges and flooding (2015).

2. Strategic Adaptation Framework

The development of the 'National Climate Change Adaptation Framework' (NCCAF) in 2012 was definitely perceived as a step in the right direction in relation to supporting coastal climate change adaptation in Ireland. The NCCAF outlines how Ireland is going to adapt to the severe impacts of climate change which Ireland will experience. The NCCAF calls upon "relevant Government Department Agencies and local authorities to commence sectoral and local plans, and to publish these plans by mid-2014"(2012,3). However, the NCCAF fails to clearly outline how the relevant sectoral agencies should adapt to climate change. The NCCAF mentions briefly the impacts of climate change on coastal areas, but it fails to outline how to train coastal managers, how to prepare coastal vulnerability assessments, how to engage members of the public and how finance adaptation measures. It is now almost the middle of 2015 and there is little evidence to suggest that the different government departments have prepared adaptation plans.

3. Changes to Local Planning Schemes

There is some evidence to suggest that local authorities are making changes to local planning schemes to deal with impacts of climate change. The Environmental Protection Agency (EPA) Climate Change: Scenario's and Impacts for Ireland report (2003) recommends that local authorities with coastlines to use a sensible approach to coastal management for sea level change.

- No new building or new development within 100 m of 'soft' shoreline.
- no further reclamation of estuary land;
- no removal of sand dunes, beach sand or gravel; and,
- all coastal defense measures to be assessed for environmental impact(2003)

The OPW together with Department of Environment, Heritage and Local Government have also produced "Planning Guidelines for Local Authorities" which outlines a framework to consider flood risk at all stages of the planning process and also the need to take into consideration climate risks (2009). However, Ireland's National Spatial Strategy (2002-2020) and National Development Plan(2007-2013) which are the main frameworks for local planning in Ireland do not take into account coastal climate risks (Flannery et al. 2015).

Many coastal counties around Ireland have integrated these guidelines into their county and city development plans and strategic environmental plans (Flannery et al. 2015). However, studies have shown that these regulations are not always implemented at the local level; developments are still occurring in areas which will be prone to coastal climate change impacts (Flannery et al. 2015).

4. Changes to Infrastructure Design and Delivery

Excluding a few regional initiatives, there has not been any overall changes or policies developed to support changes of infrastructure design and delivery to take into account coastal climate risks in Ireland. When it comes to coastal protection Ireland, there is still a tendency to favour hard infrastructure over more natural infrastructure. The most common types of protection measures in Ireland are revetment structures such as sea walls, rock armoring and dykes (Murphy 2014). Due to the lack of monitoring of the Irish coastline, it is difficult to comprehend how much of the Irish coast is armored, but studies have found that roughly four percent of the Irish coastline is protected (Devoy 2009). In the past, many of the protective measures were conducted in an ad-hoc fashion which can have a negative impact on the coastal environment (O'Connor et al. 2009). Even with the transfer of responsibility of coastal protection works to the OPW, so far they have had a propensity to employ only engineering projects and to protect existing coastal protection infrastructure as opposed to more ecological measures (Flood and Schechtman 2014).

Further evidence highlighting the lack of changes to infrastructure design and delivery in Ireland to take into account coastal climate hazards was observed following the serious series of storms and coastal flooding of late 2013 and early 2014. The government approved €70 million in funding for repairing coastal protection infrastructure, roads and other coastal assets without fully taking into consideration the predicted increase in sea-level and storm reoccurrence due to climate change (Department of Environment, Community and Local Government 2014). The amount of damage demonstrated that hard infrastructure measures will not protect the coast adequately against the predicted frequency of future severe storms and there is an urgent need to consider changes to infrastructure design and delivery.

Despite the overall reliance on hard infrastructure, there have been some examples whereby alternative measures have been implemented. For example, beach nourishment initiatives have taken place Rosslare and Bray and a 'managed realignment' of sand dunes in Rossbeigh in County Kerry (Cooper 2013).

5. Financial Strategy for Current and Future Work

Coastal climate change adaptation in Ireland is still very much focused at the early steps of the ladder of adaptation, so at this stage developing a financial strategy for current and future work has not yet been considered a major issue.

Ireland's progress on the ladder of adaptation are being hindered by the lack of detailed coastal monitoring, a weak adaptation framework and a tendency to favour engineering coastal protection measures over alternative ones.

4 California

4.1 Physical Vulnerabilities of Climate Change in Californian Coastal Areas

The state of California in the United States is similar to Ireland in having a long exposed coastline, a coastline which is at major risk to the harmful impacts of climate change. The coastline of California is 1,100(1,700km) miles long but in addition the low lying San Francisco Bay Shoreline which is almost 275 miles in length will also be vulnerable to the effects of climate change (California Coastal Commission 2015, San Francisco Bay Conservation and Development Commission)¹. The majority of California's coastline consists of steep cliffs and terraces, while Southern California and the Bay area are predominantly low lying (Griggs et al. 2005).

Due to California's mixed topography, SLR will not be uniform. SLR will be faster and lead to more damage south of Cape Mendocino compared with the less populous northern coast (National Research Council 2012). The National Research Council predicts sea levels to rise by 12 to 61 centimetres by 2050 and by 42 to 167 centimetres by 2100 (2012). Research by the U.S Geological Survey (USGS) have observed an increased frequency and intensity of extreme storms of the latter half of the 20th century and these trends will continue until 2100(2013).

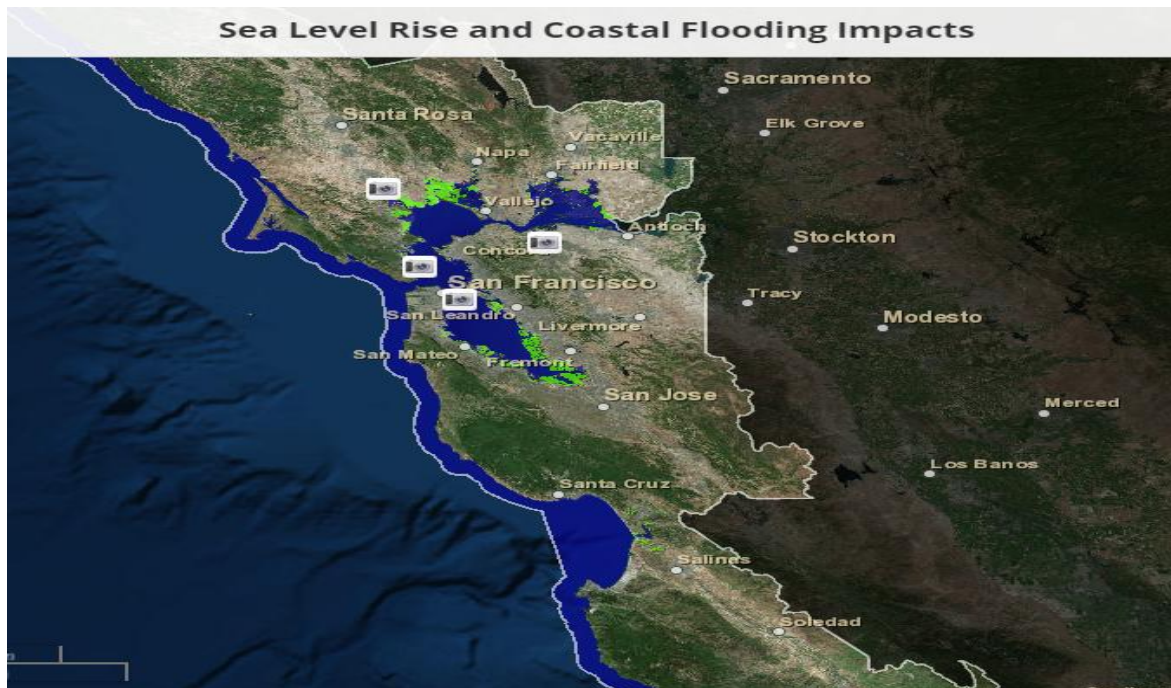


Figure 4-1 Map Showing Sea Level Rise and Coastal Flooding Impacts in California (NOAA 2015)

¹ Coastal areas in California for the purpose of this thesis includes the shorelines of the San Francisco Bay Area.

Coastal erosion and coastal flooding are two major challenges which California faces in addition to climate change. 72% of California's coastline has actively eroding cliffs (Department of Boating and Waterways and State Coastal Conservancy 2002). The rate of erosion ranges from 0-42 centimetres per year (Griggs et al. 2005). However, there are some areas where retreat occurs much faster, such as Point Ano Nuevo, which has an erosion rate of nine feet per year (Griggs et al. 2005). The low lying lands in the southern parts of the state and the San Francisco Bay area have always been prone to serious flooding (Heberger et al. 2009). High tides, storm and storm surges are all contributing factors to coastal flooding in California. Coastal flooding in California is also driven by King Tides, El Nino and El Nina weather events which are unique to the Pacific Ocean (Heberger et al. 2009). It is clear that climate change in combination with coastal flooding and erosion will put tremendous pressure on the coastline of California.

Climate change will also place major stress on California's natural eco-systems and groundwater supplies. California's coastline has over 550 square miles of wetlands and is home to many unique species; and, importantly, these wetlands play a role in natural coastal protection (Heberger et al. 2009). Saltwater intrusion from the sea-level rise poses a major threat to California's groundwater supplies (Heberger et al. 2009). Freshwater supplies are of enormous value to the state of California, especially for the agricultural sector and because of the high probability of drought occurring in California. The current drought of almost four years is not helped by the negative consequences related to salt-water intrusion of ground water supplies.

4.2 Socio-economic Vulnerabilities of Climate Change in Californian Coastal Areas

California's highly populous and developed coastal areas will be negatively impacted by predicted climatic changes. There are over 26 million people living in coastal counties and cities (Heberger et al. 2009). California's major urban centres including Los Angeles, San Diego and the San Francisco Bay area are all situated in coastal environments (Heberger et al. 2009). Critical infrastructure including roadways, rail roads, wastewater treatment plants, power plants, schools and hospitals are located at current sea level (Heberger et al. 2009). The Californian coast is one of the most economically developed areas in the United States. California's coastal economy is worth \$45.7 billion and provides roughly 614,496 jobs (National Ocean Economic Program 2005). The San Francisco Bay area, in particular, is a huge area of great economic importance. There is a wide disparity of social backgrounds with both upper classes and lower classes inhabiting coastal areas in California (Cooley et al. 2012). According to the Pacific Institute, a 1.4 meter SLR will put 480,000 people at risk from a 100-year flood event and also damage almost \$100 billion worth of coastal property (2009). The large amount of development which has occurred in California over the last century will be under threat from changes in oceans levels related to climate change.

It is clear from the above evidence that there are many similarities in the physical and socioeconomic risks associated with climate change in coastal areas of both California and Ireland and therefore seeking to understand California's response to these issues will be very beneficial to Ireland.

4.3 Coastal Governance in California

There is a significant amount of evidence to suggest that California has been highly proactive in terms of coastal climate change adaptation but there are also certain areas where the state is lagging behind. A long history of effective coastal management is one of the main strengths which California holds. Following citizens concerns about the rate of development, the Coastal Act was enacted by the State in 1972 in order to protect California's coastal resources (California Coastal Commission 2015). The aim of the Coastal Act is to "protect, conserve, restore and enhance environmental and human based resources of the Californian coast and ocean for environmentally sustainable and prudent use by current and future generations" (California Coastal Commission 2015). The California Coastal Commission (CCC) was founded in 1976 to undertake the work which is required to meet the requirements of the Coastal Act. The CCC works in collaboration with California's 76 coastal counties and cities, assisting with their implementation of Local Coastal Programs (LCPs) (2014). LCPs can be considered as general plans which govern decisions about the short and long terms conservations and the use of coastal resources (CCC 2015a). Before a coastal city or county implements or amends their LCPs, it has to be approved by the Coastal Commission. Other areas in which the Coastal Commission works include ensuring public access to coastal areas, pollution prevention programmes, as well as public education programmes (CCC 2015a).

As well as the Coastal Commission, the State Coastal Conservancy (SCC) and the San Francisco Bay Conservation and Development Commission (BCDC) are other state agencies which work to ensure the protection of the California and Bay Area shorelines. The BCDC fulfils a similar role to the Coastal Commission and has regulatory and planning authority over shoreline development in the nine bay counties (2015). On the other hand the SCC places more of an emphasis on purchasing, protecting and enhancing coastal resources in order to allow access to the shore (SCC 2015a). Over the years, the CC, SCC and BCDC have been influential in protecting and expanding public shorelines and sensitive habitats and wetlands.

Despite the many successes of coastal management in California, there have been many challenges. The CCC, SCC and BCDC all mentioned during interviews that their abilities to protect the coast is hampered by budgetary and resource constraints. The success rate of the LCPs varies significantly, with some counties and cities faring better than others. The CCC has a major backlog in dealing with violations of the coastal act including the blocking of public access to the shoreline, unpermitted developments in sensitive habitats, and unpermitted land alteration. More than 80% of California's LCPs were certified over 20 years ago and are in need of updating (CCC 2014). There are also areas along the coast which do not have certified LCPs. The Coastal Act dates back to 1976 and does not take into account the major changes to the coastline since that time; neither does the act accommodate the major advances in scientific information on coastal climate issues. There is also no legal obligation for coastal counties to undertake or update their LCPs (CCC 2014).

In comparison with Ireland, California has much more integrated and formalized coastal management governance system which puts it in a better position to respond to coastal climate risks.

4.4 Coastal Climate Change Adaptation in California

1. Climate Risk Analysis

California has been carrying out extensive coastal climate risk analysis for an extensive period of time. As part of its Climate Change Adaptation Strategy, The California Climate Change Centre is already conducting its fourth state wide vulnerability assessment (2015). All of the vulnerability assessments have highlighted the threats which climate change will pose to California's coastal areas. The National Research Council has completed a study looking at the impacts of SLR on the west coast of the United States, including California (2012). The Pacific Institute has completed a state wide study on the impacts of Sea Level on the Californian Coast as well as another study looking at social vulnerabilities related to climate change impacts (2009, 2012). The CCC, BCDC and SCC have acknowledged the risks associated with climate change and have undertaken a considerable amount of research related to coastal climate risk.

As well as just public vulnerability assessments, California is also undertaking comprehensive monitoring programmes of the California coastlines. The National Oceanic and Atmospheric Association (NOAA) and the U.S Geological Survey (USGS) and the Ocean Protection Council (OPC) are developing tools, maps and models to understand coastal climate vulnerabilities.

Coastal Climate Risk Analysis has not just been limited to state and federal agencies. Many coastal cities and counties are actively undertaking studies to understand their local vulnerabilities. For example, the cities of Santa Barbara and San Diego have both undertaken comprehensive SLR vulnerability assessments (CNRA 2013).

2. Strategic Adaptation Framework

In terms of developing a strategic adaptation climate change framework, California has proven to be one of the most progressive states in the U.S for taking action. In 2009, the California Adaptation Strategy (CAS) was launched following Executive Order S-13-08. The California Adaptation Strategy which is led by the Californian Natural Resources Agency (CNRA), in conjunction with multiple other state agencies, aims to use the best known science to assess the impacts from climate change in seven sectors and provide recommendations on how to manage those risks (2009). The Climate Change Adaptation Strategy puts a major emphasis on the impacts of sea level rise in coastal areas (CNRA 2009). Members of the Climate Adaptation Working Group recommended that three of the six priority strategies should address sea level rise:

- Strategy 3 requires agencies to prepare sea-level rise plans,
- Strategy 4 requires local authorities to amended LCPs and general plans so that they include climate change impacts,

- Strategy 5 calls for the completion of a State-wide Sea-Level Rise Vulnerability Assessment every five years (CNRA 2009).

The CAS was updated in 2013 with the publication of ‘Safeguarding California: Reducing Climate Risk’ which presents the most up to date information regarding coastal environments, transportation infrastructure, water supply and other developments. The update highlighted the issue of toxic material released from flooded coastal facilities such as underground storage tanks, superfund sites and closed landfills (CNRA 2013).

Despite the many benefits associated with the CAS, there are also many weaknesses with California’s strategic adaptation framework. In comparison with California’s mitigation activities, the pace of adaptation is much slower (Davis and Chornesky 2014). Budgetary resources and human resource constraints have limited the amount of adaptation work which can be carried out by the state coastal agencies. The CAS also places a strong emphasis on assessing local and regional vulnerabilities, but it does not evaluate the social and economic tradeoffs associated with alternative adaptation strategies (Davis and Chornesky 2014). The CAS does not adequately address how to deal with the sheer amount of existing public and private development and social infrastructure, as well as the protective armoring located on California’s coastline. Competing environmental interests, most notably the current drought are taking the attention away from coastal climate change issues.

Another criticism of the CAS is the lack of consideration for coastal bio-diversity issues (McGinnis and McGinnis 2011). California’s coastal areas are a hotspot for bio-diversity but human development pressures has led to significant degradation of California’s coastal marine ecosystems (McGinnis and McGinnis 2011). The effects of climate change will degrade California’s remaining wetlands and foreshores which are home to numerous animal and plant species (McGinnis and McGinnis 2011). However, there is no law or policy which mandates coastal cities or counties to take into account any impacts to biodiversity in their plans (McGinnis and McGinnis 2011)

3. Changes to Local Planning Schemes

In response to the Climate Change Adaptation Strategy, a significant number of coastal cities and counties have started a process of making changes to their local planning schemes. While only limited numbers of cities and counties have actually amended their LCPs and general plans to take into account climate changes impacts, many cities and counties are carrying out coastal vulnerability assessments which will inform updates to coastal plans. Coastal cities and counties are making a conscious effort to reach out to many members of their communities and to other key stakeholders as they update their planning schemes. The CCC, BCDC and the SCC have all been highly proactive assisting coastal cities and counties. The CCC is engaging with cities and counties throughout the state and is assisting and funding them with updating their LCPs to take into account climate change considerations (2015). The BCDC is working with counties around the Bay via planning efforts and projects that address climate change (2015). The SCC is also funding a variety of projects which are helping California to adapt to climate change (2015b). As well as the three coastal authorities, there are many research institutions and non-profit organisations that are also assisting coastal cities and counties with guidance documents and with other support tools to assist them in to make changes to their local planning schemes.

However, as was mentioned before with regard to the subsidiary structure of coastal management in California, the capability to update local planning schemes depends on the resources of the coastal city and county in question. To date, there are counties and cities that are making much more progress in updating their LCPs and general plans to take into account climate change consideration than other under less resourced ones(CCC 2014).

4. Changes to Infrastructure Design and Delivery

In terms of making changes to infrastructure design and delivery, California is still in the early stages but there are many examples of alternative approaches to infrastructure design and delivery emerging in California. There are many pilot studies taking place along the California coastline experimenting with ecological green infrastructure tools such as wetland restoration, sand dune restoration and other horticultural coastal protection measure (SCC 2015). California's scientific and research community are also currently undertaking studies to test the viability of natural coastal protection measures in many locations throughout California. Surfers Point in Ventura County and the seaside town of Pacifica have both completed successful managed retreat operations (Feifel 2010). The CCC has also become much stricter with regards the permitting of seawalls by ensuring that they have limited ecological impact and shortening the period of the permit to take into account future coastal climate risks(CCC 2013). The California Department Transportation (Cal-Trans) has already begun moving part of Highway 1 inland in response to erosion and predicted SLR (2012).

However despite these few examples, one of the major challenges for making changes to designs and delivery is the sheer amount of existing development, social infrastructure and coastal protective armoring on the Californian Coast. Griggs et al. found 110 miles or 10% of California's coastline has now been protected or armored (2005). Despite, efforts by coastal authorities, there is still development occurring, new coastal walls are constructed and existing ones are been updated (Griggs et al 2005).



Figure 4-2 Coastline Development at Case Verde, Monterey Bay California

5. Financial Strategy for Current and Future Work

California has made some efforts in developing a financial strategy for current and future work. The CCC, BCC and the OPC are funding projects to assist coastal cities and counties to update the LCPs and general plans to take into account climate hazards. However, there is no real indication yet of how to finance the more costly stages and big infrastructure projects related to coastal climate change adaptation.

4.5 Evaluation of Coastal Climate Change Adaptation in Ireland and California

Based on the ladder of adaptation as devised by Gurrann et al., table 4-1 will evaluate Ireland's and California's efforts for coastal climate change adaptation using the following scale;

0 = No action

1= Underway

2=Completed

3= Implemented

Ladder Steps	Ranking		Ranking	
	Ireland	Details	California	Details
Climate Risk Analysis	1	Broad overview of national coastal risks but need for more comprehensive long term monitoring programmes.	3	Comprehensive state-wide vulnerability assessments and coastal monitoring programmes.
Strategic Adaptation Framework	2	Launch of NCCAF in 2012 but lack of clear guidelines or resources on how to implement it.	3	CAS has been completed with a large amount of coastal cities and counties already in the implementation stage.
Changes to local planning schemes	1	EPA and OPW has produced guidelines to incorporate coastal climate risks in planning but not always enforced at local level.	1	Some coastal cities and counties have already implemented changes while many others are in the process.
Changes to Infrastructure and Design and delivery	0	Little evidence of significant changes to infrastructure design and delivery.	1	Examples and pilot studies of changes to infrastructure designs and delivery taking place but no overall changes to infrastructure design and delivery.
Financial Strategy for current and future work	0	No financial strategy for current or future work as of yet.	1	Funding for coastal climate risk projects but no long term funding secured for coastal climate change adaptation.

Table 4-1 Evaluation of Coastal Climate Change Adaptation in Ireland and California

It is clear that in comparison to Ireland, California is making more progress on the ladder of adaptation particularly in terms of risk analysis, development of an adaptation framework and changing infrastructure designs and delivery. The Ladder of Adaptation points out that California is making more progress with coastal climate risk analysis, policies to support coastal climate change adaptation and experimenting with more natural coastal protection measures. The following chapter will examine more specific ways in which California's coastal climate change adaptation efforts can assist Ireland.

5 Lessons for Ireland from California

5.1 Legislation and Planning

In relation to legislation and planning, there are several valuable lessons that California can teach Ireland regarding coastal climate change adaptation. One of the major criticisms of Ireland's adaptation efforts is the lack of a clear national coastal policy and ill-defined coastal responsibilities. California is in the fortunate position of having coastal legislation which spans almost 40 years and provides clear guidelines and defines responsibilities on how to deal with coastal issues. In order to oversee the implementation of the Coastal Act, California has three state agencies, the CCC, BCDC and SCC which work to assist local governments, and which conduct change and lobby for change. When the California Climate Change Adaptation Strategy came into force, California already had a well established coastal policy and three state agencies with the expertise and the authority to prepare California's coastal areas for the climate change risks. California's strong coastal policy has made, and will continue to make, adaptation easier in coastal areas in the future. If Ireland was to establish a clear policy framework and appoint a new state agency or allocate responsibility to an existing government agency, Ireland would be in a much better position to manage the many physical and socio-economic threats related to climate change in coastal areas.

In addition to the California Adaptation Strategy, the strong legislative approach which California takes in relation to climate change issues in general is also another important take home message for Ireland. California has already adopted thirteen bills and signed four executive orders to encourage greenhouse gas reductions. Even in 2015, Californian Governor Brown introduced and signed an executive order (B-30-15) to extend the greenhouse gas reduction target to 40% below 1990 level by 2030. Ireland only published its Climate Action and Low-Carbon Development Bill in 2015 which aims reduce emissions and move to a low carbon economy by 2050 (McGee 2015). The Irish Bill fails to outline any explicit targets for GHGs emissions reduction or a definition of what is a low carbon economy (McGee 2015). As was mentioned previously, in the long term, reducing in GHGs can slow the rate of SLR, so it of great importance that Ireland learns from California about the importance of pursuing aggressive mitigation policies to compliment adaptation efforts.

The fact that the California Climate Change Adaptation Strategy puts an emphasis on a city and county level approach to coastal climate risk planning is instructive (CNRA 2009). One of the key elements of coastal climate change adaptation in California is the requirement for coastal cities and counties to update their LCPs to include climate change risks. The fact the climate change considerations are being taken into account in LCPs is useful measure in ensuring that future development does not take place in locations vulnerable to the impacts of sea level rise. Including climate change impacts in the LCPs can be a useful litigation tool if legal action is taken against a decision to refuse a new coastal development or a sea wall. Furthermore, LCPs require input from multiple local stakeholders and this can contribute to the long term success of the plan. The introduction of local and city level guidelines to coastal adaptation planning could be useful in Ireland where there is already a well-established system of city and county councils. Local governments in Ireland could develop a similar coastal protection guidance document which assesses coastal vulnerabilities and identifies adaptation options and such guidance might be integrated into existing local development plans. In both Ireland and California, the vulnerabilities in coastal areas vary significantly and this is a further reason why a localised approach should be used in Ireland.

Coastal counties and cities in California have already been developing their own policies to prepare for the impact of climate change and their ideas would be useful for Ireland. The city of Malibu's LCP states that the "siting and design of new shoreline development and shoreline protective devices shall take into account anticipated future changes in sea level" (The City of Malibu 2013, 4). The City of Santa Barbara LCP requires that new developments should be "set back far enough from the bluff edge to ensure its safety for its economic life, usually from 50 to 100 years" (2013, 16). The CCC is working with many coastal counties and cities to ensure that the new permits for seawall developments are limited to 20 years in order to take into account future coastal risk (2013b). There are many other examples of coastal and bay shoreline cities and counties in California which have already developed, or are in the process of developing, policies to prepare for rising seas, coastal flooding and more extreme weather events.

Another example of updating planning legislation to take into account SLR was in late 2014, when the San Francisco Department of the Environment, in collaboration with Public Utilities Commission and Planning Department and Capital Planning Committee issued a document entitled a "Guidance for Incorporating Sea Level Rise into Capital Planning in San Francisco" The Guidance provides a step-by-step approach for City and County of San Francisco (CCSF) departments enabling them to consider sea level rise vulnerability, risk and adaptation planning within their department's Capital Plan (CPC 2014). The guidance also outlines the best recommended adaptation planning processes that city departments should follow (CPC 2014). The guidance provides examples of how city departments should consider the effects of SLR in its capital planning processes (CPC 2014). The examples include the construction of a new fire station, the renovation of an existing waterfront buildings and the construction of a new shoreline park (CPC 2014). A Project Planning Checklist was included in the guidance which helps project managers to implement the SLR guidance (CPC 2014). The San Francisco Planning Committee will use this guidance in the immediate and longer term to determine whether or not the Capital Plans have adequately addressed SLR (CPC 2014). These cities and counties are realizing their vulnerabilities and taking action to counteract them. This could be a useful lesson for Ireland whereby coastal cities and counties develop adaptation policies based on their vulnerabilities and integrate them into existing policy frameworks without waiting for national direction.

Another piece of legislation which may be useful for Ireland is the recently enacted Assembly Bill (A-B) 2516 Sea level Rise Planning: Data base (2014). The bill mandates the Natural Resources Agency to establish an online database whereby state government departments, commissions and local planning agencies must file studies that they have undertaken on risks from SLR and any planned defences. The aim of the legislation is to promote regional co-ordination and sharing of ideas. As Ireland's coastal climate change adaptation process gets underway, a similar kind of legislation could be useful in helping to speed up the process and encourage integration between the different coastal management sectors

Unlike Ireland, the fact that California has a strong tradition of coastal management has resulted in the adaptation process being far easier. The comprehensive localised approach which California is adopting could also be a useful lesson for Ireland as coastal vulnerabilities vary in different counties and cities.

5.2 Financing Coastal Climate Change Adaptation

There is no doubting the fact that Ireland will need to spend a significant amount of money on coastal climate change adaptation. Ireland could learn how to finance coastal climate change effectively from California's tried and tested funding mechanisms. California has three main sources of funding for coastal adaptation activities: (i) Ocean Protection Council (OPC) - Sea-Level Rise Grant Program (ii) Coastal Commission LCP Planning Assistance Program and (iii) Climate Ready Grants which are administered by the Coastal Conservancy (2015). The OPC grant which is administered in collaboration with the CCC is given to coastal cities and counties to assist them in undertaking activities which include sea-level rise modelling, vulnerability assessments, and adaptation planning and policy (2015). The CCC LCP grant is available to help local governments update existing LCPs or certifying new LCPs and these updates may address the impact of climate change (SCC 2015c). The Climate Ready Grants from the SCC are awarded to projects that address sea-level rise impacts and for other projects such as sustainable agriculture, urban greening, conservation and education (SCC 2015c). The SCC grants are not limited to local governments; non-governmental organizations (NGOs) and community organisations can apply for Climate Ready grants in order to complete projects. The latest California state budget also included the creation of a "Climate Resilience Account" for coastal agencies to continue addressing sea level rise and climate change (SCC 2015) The administration of these grants is carried out in a very transparent process and all details of how the money is being used are publically available

Rather than putting the entire financial burden on the three main coastal agencies, there are other federal agencies which are funding coastal climate change adaptation initiatives in California. National Oceanic and Atmospheric Administration (NOAA) is providing grants to help coastal communities to prepare for the impacts of climate change as part of its SEA Grant Initiative (Aminzadeh 2014). The Federal Emergency Management Agency (FEMA) as parts of its Hazard Mitigation Assistance Program is providing grants for reducing risks in coastal areas (Aminzadeh 2014). The Fish and Wildlife Service (FWS) are also providing grants to protect fish and wildlife and their habitats from climate change (2015).

California has also devised alternative funding mechanisms which can generate income for coastal adaptation measures. In cases where the Coastal Commission has no choice but to grant a permit for a seawall, it can add a condition where the developer must pay an in-lieu fee to mitigate for the loss of an acre of beach and its recreational value caused by the construction of the seawall (Griggs et al. 2005). The fee collected is then used to purchase replacement beach property elsewhere (Griggs et al 2005). However, there are many difficulties in calculating the value of lost sand and the loss of public beach access and the mitigation fee amount is challenged in the courts by the developers (Griggs et al. 2005).

The way in which California is administering funding in this area and the types of activities which are being funded could prove useful examples to Ireland in relation to how it finances adaptation activities. There are opportunities in Ireland for local governments, research institutions, and NGOs to apply for funding for projects from Irish government and European sources; the Californian grants program could help inform their application process.

5.3 Natural Coastal Protection Measures

As previously mentioned, Ireland's coastlines are at risk from a range of both physical and socio-economic hazards. Furthermore, as has been mentioned, that there is lack of coastal protection and when the coast is protected it is usually with hard infrastructure. Traditionally California has also tended to rely upon hard infrastructure solutions, but in more recent times there have been many notable examples of more natural coastal protection measures in California and many of these examples may be helpful in locations throughout Ireland.

Wetland restoration projects can be a useful method of building ecological resilience and buffering the impacts of SLR and storms on the shoreline. Both Ireland and California have a long history of wetland destruction due to land reclamation and drainage. There are many active wetland restoration projects taking place in California, particularly in the bay area. The bay area will be exceptionally vulnerable to any sea-level changes due to the size of the bay and the large developments situated on its shoreline. The Bay Area estuary was once home to 200,000 acres, but over time that figure has dropped to 45,000 healthy acres (Tam 2014). Due to the shallow nature of the bay, as the economy began to grow, large sections of the bay were filled-in to cope with the increase in developments (Tam 2014). One of the most notable wetland restoration projects in the bay area is the 'South Bay Salt Pond Restoration Project' which is actively restoring over 15,000 acres of a former industrial salt pond to tidal activity and managed ponds (Tam 2014). The lands were acquired from Cargill by state and federal agencies (Tam 2014). The project is being coordinated by state and federal agencies, park districts, and flood control districts (Tam 2014). Funding for the project was acquired from the U.S. Fish and Wildlife Service, the U.S. Army Corps of Engineers, the National Oceanic and Atmospheric Association (NOAA), the Wildlife Conservation Board and the Hewlett Packard and Moore Foundations (Tam 2014). The goal of the project is to restore wetland habitats, provide flood control and allow for public access and recreation (Tam 2014). The project is using an adaptive management framework to measure and observe changes on the ground and use this information for land management decisions.

The use of adaptive management framework is useful for dealing with issues in the project which relate to changing habits, invasive species, water quality and impacts of public access on the wetlands (Tam 2014). To date, the project has had a number of successful achievements including the opening of public trails in three project areas: Eden Landing, Alviso and Ravenswood (Tam 2014). The project has also restored over 3,000 acres to tidal function. However, there are still thousands of acres of wetlands in the bay area which need to be restored and funding and political support for the project is not guaranteed. In order to overcome these difficulties, non-profit organisations such as Save the Bay and SF Bay Joint Venture are lobbying for more funding and for the setting up of a regional agency to expand the project (Tam 2014). Wetland restoration projects in Ireland could play an important and highly beneficial role through their use as natural coastal protections as many of Ireland's cities and towns are located around estuaries and bays. Besides flooding and storm protection, wetland restoration could help Ireland with improving water quality, carbon sequestering, providing habitats for birds and fish as well as tourism opportunities.



Figure 5-1 South Bay Salt Pond Restoration Project before and After(South Bay Salt Restoration Project 2015)

Managed retreat is a highly contentious coastal protection option as it entails the removal of infrastructure and property to allow the shoreline to migrate inland. Although it has not taken place in Ireland, there is a growing consensus, following recent storms and flooding events that managed retreat may be inevitable. California has already completed a number of managed retreat projects and is in the planning stage for many more. These projects could be instructive for Ireland as the country explores how to effectively undertake managed retreat. One of California's most successful examples of managed retreat is at Surfers Point in the City of Ventura (Feifel 2010). Coastal erosion has always been a serious issue in Surfer's Point and created significant damage to a nearby bike path and parking lot (car park); in some locations almost 60 feet of land was lost and this raised serious concern for citizens (Feifel 2010). Through the 1980s and 1990s the cities principle response was to harden the coastline with concrete barriers and riprap (rock armour) (Feifel 2010). However, in 1995, the California Coastal Commission refused the City of Ventura permission to continue hardening the coastline as it was exacerbating the rate of erosion (Feifel 2010). In order to come up with an alternative solution, a working group was founded including city and non-government organisations, including the Surf Rider foundation, to address erosion using a managed retreat approach (Feifel 2010). The managed retreat strategy involved relocating the bike path and the parking lot by moving them 60 feet inland, restoring the natural beach, removing the riprap, beach nourishment and lobbying for the removal of the adjacent Matilija Dam to restore natural sand supply (Feifel 2010). Other notable examples of managed retreat are taking place in the coastal town of Pacifica where the Ocean Beach Master Plan also includes interesting elements of managed retreat. By looking at California's examples of managed retreat, Ireland can learn what steps it needs to take and what considerations need to be taken in account when undertaking managed retreat.

It is very important to point out that coastal protection for climate risk does not necessarily have to be a big budget operation or to be large in scale. Many places in California have developed effective and low scale protective projects which have proven to be effective and may be of use to Ireland. As part of their Climate Action Plan, the city of Berkeley has increased tree planting efforts along the shoreline as trees can store rainwater, reduce runoff,

delay peak flows and have higher soil infiltration rates (2009). The city of Berkeley is also proactive in maintaining and upgrading drainage systems to reduce runoff (2009). Another simple natural infrastructure measure is currently being piloted at the Seal Beach National Wildlife in Southern California where the U.S Fish and Wildlife Service are adding a thin layer of sediment over salt marshes in order to combat sea level rise, while also protecting endangered species (2014). The Bay Institute has developed prototypes in the North Bay Area of a number of 'Horizontal Levees' which might be described as a hybrid of traditional earthen levees and restored marshes (2013). Another small scale natural infrastructure initiative is the San Francisco Bay Living Shorelines Project which is trying to identify the best location and techniques for native oyster and eelgrass restoration as a tool to reduce wave action and protect the adjacent shorelines (2015). These simple and cost effective natural coastal protection measures could be implemented in many locations throughout Ireland.

Although, there are only a small number of natural infrastructure projects actually in the implementation stage, there is wide spread support for more natural coastal protection measures in California. The update to the CAS in 2013 calls for investment in green infrastructure to address SLR. The CCC's Draft Sea Level Rise Documents also calls for coastal managers to "embrace green infrastructure and living shorelines; avoid the perpetuation of shoreline armoring" (2013,6) The U.S Environmental Protection Agency (E.P.A) has produced a Synthesis of Adaptation Options for Coastal Areas which outlines many natural coastal protection measures (2009).

California research and scientific community is also carrying studies on the benefits of more natural coastal protection measures. For example, The Natural Capital Project, which is a collaborative effort between non-governmental organisations, is carrying out an assessment on the effectiveness of coastal habitats in reducing storm risk (2015). Another study by the Monterey Bay National Marine Sanctuary (MBNMS) on an Erosion Mitigation Alternative for the Southern Monterey Bay outlined a number of natural protection measures for the Southern Monterey Bay (2012). The report found that using alternative measures such as cessation of sand mining, rolling easement and beach nourishment would have a net benefit of 1.25 billion dollars over the next century as opposed to traditional sea wall construction (MBNMS 2012).

Another interesting source which generated ideas for natural coastal protection measures was the "International Rising Tides Competition" organised by the BCDC to try and come up with innovative design solutions to deal with SLR in San Francisco Bay and beyond (2009a). The competition was open to everyone including designers, engineers, planners, artists and ordinary members of the public. Participants were given the brief "to solve a meaningful sea level rise problem, while being environmentally smart, simply designed and transferable to other estuaries beyond San Francisco Bay"(BCDC 2009b,1). The competition sparked enormous interest and there were a large number of entrants (BCDC 2009a). There were six winning proposals. Some of the ideas included: a flexible lightweight barrier at the entrance to the bay, a self-sustaining "Folding Water" ventilated levee which acts a waterfall in the bay and mechanically regulates sea levels while also protecting the bay waters, and finally the construction of an artificial ecological systems along the San Francisco Bay shoreline (BCDC 2009a). An exhibition of all the entries was held at the San Francisco Ferry Building and was open for members of the public to view (BCDC 2009a). A competition similar to this could take place in Ireland to try and come up with innovative designs and solutions on how to deal with the impacts of climate change in coastal areas.

It is clear that natural protection measures are being taken seriously as coastal climate change adaptation options in California. Clearly, there are initiatives in California, already in the

implementation or research stage, which could be useful for Ireland in pointing out and demonstrating the benefits of natural coastal protection measures and helping Ireland to move away from a dependency on engineering coastal protection measures.

5.4 Community Engagement

It is clear that Ireland is still at the very early stages of adaptation in comparison with California and, that in order to progress, it is vital to get the public on board. Public engagement is an important element of any adaptation effort because people living in coastal areas will most definitely be affected by the impacts of climate change and thus it is important that they fully understand the risks and that they support adaptation efforts. California has placed a major emphasis on strong community engagement in its adaptation efforts and Ireland must learn about the different instruments which California is using as part of their process of interacting with members of the public.

At state level, there is also a strong emphasis placed upon citizen engagement. Even before the initiation of the California Adaptation Strategy, the Coastal Act clearly stated that “the public has a right to fully participate in decisions affecting coastal planning, conservation and development” (Section 30006) (1976). From undertaking interviews with members of staff of the CCC, they mentioned that when they published their Draft Sea Level Rise Guidance Document in 2013, it presented the document at two public hearings and hosted two online webinars. The CCC set aside a period of time to collect and publish comments, the CCC received 100 letters and over 850 comments from a broad range of actors including concerned citizens and researchers. The CCC will take on board any feedback it gets and will incorporate it into the final document.

At local level, California is also actively encouraging public participation in its adaptation planning efforts. As previously mentioned, one of the key ways in which California is implementing coastal climate change adaptation is by encouraging cities and counties to update local planning laws. Many counties and cities have developed innovative strategies to encourage public participation in the updating process of their LCPs to include climate change considerations. Marin County of the north coast is involved, and is actively engaging with citizens in the updates of its LCP (2014). Marin County is engaging with the public on its LCP update with an intergovernmental/public-private partnership known as Collaboration: Sea-Level Marine Adaptation Response Team (C-SMART) (2014). C-SMART is working to develop an understanding of how SLR may affect homes, schools, infrastructure, natural resources, and also to create an understanding about when these impacts might occur, how they might change over time, and how to prepare for them (Marin County 2014).

The city of Benicia, located on the San Francisco Bay shoreline, as part of its Climate Action Program, has developed several innovative tools to enhance public engagement in planning for SLR. Because it is younger generations who will be the worst hit by severe climate change events, the city of Benicia organised presentations at the local high school so that students could voice their thoughts and ideas (Porteshawer 2015). Workshops were also held for city and state departments, non-profits, private companies and business holders, residents, emergency personnel, and the arts community so as to obtain their insight and perspective for the collection of vulnerability data (Porteshawer 2015). Further information on vulnerabilities, on existing conditions and possible consequences were gathered through an online survey of asset owners and managers (Porteshawer 2015). The project educated the public about climate change risk and adaptation; the project findings were discussed with an open house evening

(Porteshawer 2015). An online engagement tool through the Open Town Hall website was created for members of the public to comment on the vulnerability assessments and to discuss adaptation options (Porteshawer 2015).

As part of Ocean Beach's Master Plan, San Francisco's Planning and Urban Research Association (SPUR) has also introduced and piloted some unique methods of working in collaboration with members of the public (Cheong 2013). SPUR was aware of the fact that the different stakeholders involved in the project would not necessarily see eye to eye on many issues and it would be difficult to get them to co-operate (Cheong 2013). For example, the Department of Public Works is perceived to be dry and poor in public communication (Cheong 2013). On the other hand, users of Ocean Beach were generally environmentalists who were uncompromising and held strong opinions (Cheong 2013). SPUR organised a workshop in order to encourage the different stakeholders to work together and overcome their misconceptions of each other (Cheong 2013). Another workshop was held where extreme scenarios were presented and participants had to choose between the maximisation of habitats, recreation, or hard infrastructure (Cheong 2013). Through this scenario exercise, participants were able to understand the challenges related to coastal climate change adaptation and the tradeoffs between the different options (Cheong 2013). The project sought to use as many channels as possible for public engagement including Twitter, multilingual fliers and the creation of two digital animations to explain complex technical processes in a simplified fashion (Cheong 2013). Similarly to Benicia, an online feedback tool was developed by SPUR to allow the public to comment on the draft recommendations (Cheong 2013).

California has developed many unique instruments in its efforts to raise public awareness about sea level change. Again, Marin County has developed a unique and innovative method of engaging with the public about climate change issues; they do this using a method which enables the public to visualize the changes of the landscape associated with SLR. (2014) The Marin County initiative received a grant of \$150,000 from the Federal Emergency Management Agency which enabled them to install two sophisticated devices called "owls" which resemble traditional viewfinders but are programmed to display how the landscape will appear under future scenarios and past conditions (Marin County 2014). Another noteworthy example of engaging with members of the public in California is the California King Tides Project which encourages members of the public to take pictures of "king tides", explaining that these "king tides," the highest tides of the day, will become the average water level of the future (2014). The project is organised by the state agencies, research institutions and non-profits who wish to engage Californians in a conversation about the future of the coasts, about identifying locations which are vulnerable to flooding and then to build databases of images which can be used by everyone to visualize, document and communicate about coastal hazards (King Tides Project 2014). These straightforward but effective citizen engagement instruments could also be applied in Ireland as a tool to focus the public's attention on coastal climate change issues.

It is obvious from the various examples of public engagement that the coastal climate change adaptation process in California has many benefits. The public engagement efforts in California have allowed citizens to get a clearer understanding of the hazards, to raise public support for adaptation measures, to obtain an in-depth knowledge of local vulnerabilities and to bridge relations between different stakeholders. These examples of public engagement in California illustrate how important community engagement will be in Ireland when it comes to deal with the question of adaptation to climate change in coastal areas. The different tools

employed in California could be used by Ireland to enhance public support and participation in the adaptation process.

5.5 Training and Information Provision

Although Ireland adopted the National Adaptation Framework in 2012, one of the major criticisms was the lack of training and the absence of support on how to implement the framework. Another criticism is the lack of monitoring and information on the coastline to support the adaptation process in coastal areas of Ireland. California has conducted a significant amount of research on its vulnerabilities in relation to the impacts of climate change. California has also produced a wide range of guidelines and tools which are available to coastal managers in California from public, private and research institutions in order to assist the managers with climate change adaptation. The sheer amount of guidance has made it far easier for California to understand its vulnerabilities and the appropriate measures which need to be taken to deal with and overcome these vulnerabilities; this guidance assists in building adaptive capacity to climate change in coastal areas.

One of ways in which California has excelled in terms of climate change adaptation is by undertaking extensive research to understand their vulnerabilities. The vulnerability assessments have taken many different forms. Some of the vulnerability assessments are related to climate change in general while other address coastal climate change specifically. Vulnerability assessments have been carried out at national, state and local levels. As well as general vulnerability assessment, other tools such as mapping and computer modelling have been developed to identify coastal climate hazards. A detailed list and overview of some of the various vulnerability assessments and tools and what they entail can be found in Table 5-1.

1. Coastal Climate Change Vulnerability Assessments Studies		
Organization	Name	Details
California Climate Change Centre(2009)	The Impacts of Sea Level Rise on the California Coast.	Detailed analysis of California’s infrastructure, property and population at risk from projected SLR.
The Public Policy Institute of California(PPIC)(2012)	California Coastal Management with a Changing Climate.	Examine the most important issues facing coastal managers.
BCDC(2009b)	Living with a Rising Bay: Vulnerability and Adaptation in San Francisco Bay and on its shorelines	Focuses on impacts of sea level rise on the San Francisco Bay area and how local governments can respond.
National Academy of Sciences(2012)	Sea-Level Rise for the Coasts of California, Oregon and Washington: Past, Present and Future	Comprehensive regional projections of the changes in sea level expected in California, Oregon and Washington.

2.Coastal Climate Change Vulnerability Assessment Tools		
Organization	Name	Details
NOAA(2015a)	Digital Coastal SLR viewer	Creates maps of potential impacts of SLR along the coast and related information and data for community officials.
NOAA(2015b)	Coastal Inundation Tool Kit	Tools which helps communities to understand and address coastal inundation issues.
Climate Central (2015)	Surging Sea tool	Maps showing threats from SLR and storm surges in coastal cities and states.
Point Blue Conservation(2015)	Future San Francisco Bay Tidal Marshes Tool	Maps illustrating how sea level rise may change the extent of tidal marsh and bird species distribution over next 100 years and also inform decisions about adaptation planning.
USGS(2015)	CoSMOS(The Coastal Storm Modeling System (CoSMoS)	Detailed predictions of storm induced coastal flooding, erosion and cliff failures.
FEMA(2012)	California Coastal Analysis and Mapping Project (CCAMP) and Open Pacific Coast	Pilot study to update flood insurance maps to include coastal climate risks.

Table 5-1: Overview of some of the various vulnerability assessments and tools in California

As well as developing extensive vulnerability assessments and tools, California has also produced a wealth of guidance documents and tools to assist coastal managers and other interested parties on how to prepare for the impacts of climate change in coastal areas. These guidance documents are being produce by federal, state, research and non-profit organisations and use the best available science. As well as just creating these support tools, the various organisations are also providing training and workshops to help coastal managers use these tools. These guidance tools are all publically available and could be a useful source in the drafting stage of guidelines and tools for coastal climate change adaptation in Ireland. Further details on the various guidelines and what they entail can are outlined in the Table 5-2.

1. Coastal Climate Change Adaptation Tools		
Organization	Name	Details
NOAA (2010)	Adapting to Climate Change: A Planning Guide for State Coastal Managers	A guide which helps coastal managers develops and implements adaptation plans.
George Town Climate Centre (2011)	Adaptation Tool Kit: Sea-Level Rise and Coastal Land Use	Provides local and state governments and their citizens with practical knowledge to help adapt to SLR
California Emergency Management Agency & California Natural Resources	California Climate Change Adaptation Policy Guide	Provides step by step guidelines for local and regional climate vulnerability assessment and

Agency (2012)		adaptation strategy development.
CO-CAT (2013)	State of California Sea Level Rise Guidance Document	Helps state agencies incorporate future sea-level rise impacts into planning decisions.
CCC(2013)	Draft Sea Level Rise Policy Document	Overview of best available science on SLR and recommends steps for addressing SLR.
BCDC(2015)	Adapting to Rising Tides (ART)	Road tested strategies on how to deal with climate change impacts of SLR and storm events in the Bay area.
University of Santa Cruz & Energy Commission (2012)	Adapting to Sea Level Rise: A Guide for California's Coastal Communities	Provides assistance for managers and planners in California's coastal cities and counties in development of SLR adaptation plans for their communities.
Natural Capital Project(2015)	InVEST Tool (Integrated Valuation of Ecosystems Services and Tradeoffs)	Coastal Vulnerability model uses geophysical and natural habitat characteristics of coastal landscapes to compare their exposure to erosion and flooding in severe weather

Table 5-2 Overview of Coastal Climate Change Adaptation Tools in California

California has also been instrumental in participating in initiatives which allow coastal managers to obtain and share information related to coastal climate adaptation. The California Climate Commons is a website where coastal managers can quickly find information they need to support their adaptation efforts (2014). The Climate Adaptation Knowledge Exchange (Cake) is an online platform which provides information about on-the-ground climate change adaptation projects (EcoAdapt 2015). CAKE was established by the environmental think tank EcoAdapt: using interview and surveys it synthesizes how people are responding to climate change and places these responses on an interactive online map for anybody to read (EcoAdapt 2015). Several coastal communities in California have already participated and have shared details of their adaptation efforts on the online platform (EcoAdapt 2015). The Georgetown Climate Centre has an online database called “The Adaptation Clearing House”, where policy makers and others can get ideas of adaptation options (2015). The first California Adaptation Forum, which took place in 2014, is another example of how the state is encouraging different stakeholders to learn from each other’s efforts and to work together in implementing climate change adaptation. The passing of AB 2516 Sea Level Rise Data Base legislation will further increase collaboration between the different stakeholders in California (2014).

The strong emphasis which California places on both understanding and tackling the challenges related to coastal climate change has definitely aided, and will continue to aid, adaptation in California. The huge amount of information related to coastal climate change issues produced in California should highlight the importance to Ireland of generating large of amounts scientific data which would support coastal climate change adaptation. Although, the contexts of theses vulnerability guidelines are related to California, there are methodologies, ideas and tools there which could be highly applicable to assist Ireland in gathering information to assess its coastal climate hazards. The various vulnerability assessments,

guidelines and knowledge sharing platforms are undertaken in a very transparent manner and open for anyone to see.

5.6 Multi-stakeholder and regional co-ordination

One of the major obstacles for coastal climate change adaptation in Ireland is that there are too many state bodies responsible for coastal issues and little formalised integration between them. However, there is no denying the fact that the impacts of coastal climate change will affect many different stakeholders in Ireland, so it is essential to get as many stakeholders as possible involved. As well as fostering public engagement, California is also working hard to integrate other key stakeholders (public and private) into the adaptation process. Ireland can learn from California about the benefits of engagement and about what steps need to be taken to integrate key stakeholders into the adaptation process.

Ireland is similar to California in having essential infrastructure located in coastal areas such as roads, energy, and ports which will be at risk to the impacts of climate change. California has been successful in engaging its ports, airports and road infrastructure authorities into an adaptation process. The California Department of Transportation CAL-TRANS is also preparing California's road infrastructure for the threats associated with climate change (2011). Cal-Trans have prepared a report entitled 'Guidance on Incorporating Sea Level Rise' (2011). Cal-Trans have also produced Climate Change Adaptation Hot Spot Map which identifies areas vulnerable to climate effects (2012). Cal-Trans has re-routed major roads in areas which will be vulnerable to sea level rise and erosion and new road construction projects in at risk areas are being asked to analyze the impact of sea level rise before obtaining a permit for the project(2011).

The California Energy Commission (CEC) is also very much taking into account climate change considerations into its work. The CCC and CEC have signed a memorandum of understanding that any CEC plans for locating or modifying of power plants that take places in the coastal zone must be reviewed by the Coastal Commission (2005). When The CEC is making its final decision about a project in a coastal area, they must take the recommendations of the CCC into account, unless they find that the recommendations are not feasible or have great adverse environmental impacts (2005).The co-operation between the CCC and the CEC was highlighted in the Huntington Beach Energy Project where recommendations from the CCC were taken on board when CEC when deciding on where to site the project (2014).

California's ports and its many airports will be at risk; these ports and airports are beginning to realize the vulnerabilities and the need to adapt. The Port of Los Angeles has undertaken a comprehensive assessment of its vulnerability to a sea level rise(Atkins 2011). The study has also developed possible adaptation options including raising wharfs, piers, bridges, transport connections and sewage systems (2011). The Unified Port of San Diego has adopted a Climate Mitigation and Adaptation plan on how to address vulnerabilities related to SLR (2013). Oakland, San Diego and San Francisco airports are working towards developing ideas on how they can adapt to the impacts of climate change (Climate Central 2013).

Even at city level and county level, California has been successful in engaging with as many stakeholders as possible. The Ocean Beach Master Plan developed by SPUR made a large effort to engage a wide range of stakeholders (Cheong 2013). In order to have a balanced approach at the early stages of the project, SPUR reached out to businesses and residents, directors of city agencies and elected officials and formed advisory, steering and technical

committees (Cheong 2013). SPUR organized public workshops with all the different stakeholders and channeled their input into the master plan. The Sea Level Rise Adaptation Strategy for San Diego is also another good example of the benefits of integrating as many key stakeholders as possible. The Adaptation Strategy which was facilitated by Local Government for Sustainability (ICLEI) brought together a range of public agencies and private sector representatives, and held workshops in order to reach consensus on how proceed with the adaptation strategy (2011). The multi-stakeholders helped to identify the primary vulnerabilities related to sea level rise and to devise ten comprehensive strategies (ICLEI 2011).

As well as integrating local stakeholders and other state wide organizations, California has also been proactive in coordinating regional coordination initiatives. The Bay Area Ecosystems Climate Change Consortium (BAECCC) was established to bring together natural resource managers, planners, scientists and other stakeholders together and hold meetings, workshops and projects to secure the ecological benefits of the bay (2015). BAECC is putting emphasis on how to protect the bay shoreline from the negative impacts of climate change (2015). The Monterey Bay National Marine Sanctuary (MBNMS) and the Centre for Ocean Solutions (COS) have recently established The Adapt Monterey Bay Project which is bringing together key stakeholders from Monterey Bay area in order to streamline adaptation efforts in the region (2014).

The case of California illustrates that involving key stakeholders at the early stages of adaptation will make the process of making difficult adaptation decisions much easier. As California's multi-stakeholders and regional co-ordination approach illustrates that effective coastal climate change adaptation is not something which can be completed in isolation by one single government entity; it must be undertaken in a coordinate manner by all parties who hold interests in coastal areas. Therefore it is of great importance that Ireland should involve and integrate as many key stakeholders as possible into its coastal climate change adaptation efforts.

6 Discussion

The aim of this thesis was to try and identify areas in which California can help Ireland to overcome the challenges which Ireland faces in relation to coastal climate change adaptation. The results of this thesis found that there are many specific lessons which Ireland can learn from California in terms of coastal climate change adaptation. California's strong stance on climate change issues and the wide variety of coastal climate change adaptation initiatives being undertaken there demonstrates the need for Ireland to progress swiftly with its coastal climate change adaptation efforts.

6.1 Factors contributing to California Successful Coastal Climate Adaptation

There are many underlying and less clear factors which can help to understand California's success with coastal climate change adaptation. It is very important for Ireland to keep these underlying factors in mind as it advances with its coastal climate change adaptation process.

Multi-benefit outcomes

From speaking with staff working with coastal climate change adaptation in California, it was mentioned that rather than looking at coastal climate change adaptation in isolation, California is undertaking initiatives which have many other environmental and social benefits. The strong legislative approach which California is taking is not just about preparing for rising seas and more frequent storms, it also aims to ensure that Californian citizens can enjoy a highly valuable free resource and maintain natural coastal habitats. The grant programmes for coastal climate change initiatives are not just being used to prepare for coastal climate risk impacts; these programmes are also being used for educating members of the public, for increasing public access to coastal areas, for piloting new ideas and for dealing with other environmental issues such as water shortages and pollution. The natural infrastructure coastal protection projects are also aiming to sequester green house gasses, increase public access to coastal areas and also to pilot the viability of new coastal protection measures. Rather than just informing the community about climate adaptation measures, California is trying to gather local knowledge to understand coastal vulnerabilities, ensure public support for coastal climate change adaptation and to build relationships between officials and members of the public. The impacts of climate change in coastal areas are also motivating members of the scientific and non-profit community to identify vulnerabilities and develop solutions on how deal with the coastal climate risk issues. The multi-stakeholder and regional co-ordination approach is helping to facilitate better working relationships with different coastal stakeholders.

Small but effective steps

California coastal climate change adaptation efforts illustrate that coastal climate change adaptation does not have to entail large infrastructure or expensive projects and that small scale initiatives can be highly effective. Updating local planning laws, engaging members of the public and integrating multiple-stakeholders do not require large budgets or drastic policy changes. Some of the natural infrastructure projects including planting trees in coastal areas; oyster and eelgrass restoration and adding a thin layer of sediment on top of salt marshes are

not costly exercises. Moreover, natural coastal protection measures are often cheaper than hard infrastructure projects in both the short and long terms, have a smaller ecological footprint and are visually more appealing.

Imagination and Creativity

The use of creativity and imagination across the board in California's coastal adaptation efforts is another consideration which Ireland should take into account. Rather than just producing reports and enacting legislation, California is devising unique coastal climate change adaptation measures. The 'Rising Tides' design competition, the 'King Tides' photo exhibition and Marin County's sea level rise owl viewer and the other community engagement mechanisms are good examples of how to come up with distinctive adaptation options. The creative elements of California's adaptation process illustrates that negative impacts of climate change can be dealt with in a positive and enjoyable manner.

Awareness that Coastal climate change adaptation is a difficult process

From studying California's coastal climate change adaptation efforts, it is also apparent that coastal climate change adaptation is not an easy process and that there are many difficulties. Despite the major efforts been made by California and irrespective of the broad range of policies and different actors working with coastal climate change adaptation, there are still many obstacles. While some counties and cities are forging ahead, many other coastal counties and cities lack the expertise and resources to undertake the necessary adaptation measures. However, from my interviews with officials working with coastal climate change adaptation in California, it became clear that there is an awareness of the barriers related to coastal climate change adaptation and they are trying their best to overcome them.

Resilient Approach

It is clear from studying California's coastal climate efforts that most of the work entails activities such as vulnerability assessments as opposed to large scale infrastructural change projects. Therefore it can be argued that California is building up resiliency to the impacts of climate change in coastal areas. Through carrying out detailed coastal risk assessments, engaging with members of the public and other key stakeholders, California is preparing for the severe impacts of climate change in coastal areas. With increases in flooding and storm damage associated with climate change, California will be able to respond effectively due to its comprehensive knowledge of the threats. This resilient approach is nothing new to California as it already has a comprehensive emergency response framework to deal with potential earthquakes and tsunamis.

6.2 Coastal Climate Change as a positive opportunity for Ireland

Aside from the threats, it also became apparent in this thesis that the impacts of climate change in coastal areas can offer Ireland many opportunities. Ireland could become a leader in piloting coastal climate change adaptive solutions and could act as a model for other countries. Ireland can also be a leader for piloting natural coastal protection schemes that other vulnerable countries might learn from. Ireland also has tremendous wave energy capacity already and the predicted increase in wave height associated with climate change means that

Ireland could be a world leader in terms of wave energy production. A study by the wave energy consulting firm SQW Energy found that a fully developed all Ireland ocean energy sector could be worth about €9 billion (Engineers Ireland 2011). Considering that Ireland currently imports 86% of its own energy resources and relies heavily on fossil fuels, wave energy could reduce Ireland's imported energy dependency and carbon foot print significantly (Engineers Ireland 2011).

Ireland is also in the fortunate position that the scales of the coastal climate vulnerabilities are much smaller in comparison with California. Ireland's coastal population is only a fraction of California's, as is its accompanying social infrastructure and development. California has also located housing units in much greater density and proximity to the coastline than is the case in Ireland. The disparity of the scale of impacts between Ireland and California means that it should be much easier for Ireland to deal with coastal climate change issues. But, it is very important that Ireland does not remain complacent when it come to dealing with coastal climate change issues. The serious storms of the winter 2013-2014 highlighted, with great intensity for the general public, Ireland's coastal vulnerabilities and gave an insight of what is expected in the future. The level of damage caused by the storms was unprecedented; locations which were previously not prone to flooding were flooded. Ireland should act now and develop a coastal climate change adaptation policy.

The fact that Ireland is a member of the European Union must be considered an important support mechanism for coastal climate change adaptation. The European Commission has recently adopted a new interregional cooperation programme for Ireland and Wales which is allocating €27.6 million for adaptation of the Irish Sea (and its coastal communities) to climate change(2015). As was mentioned previously, The E.U MSFD which calls for consistency between marine and terrestrial policy may put pressure on Ireland to integrate coastal stakeholders into collaboration on coastal climate change issues (2014). Further updates to the European Union's Adaptation Strategy should also act as an impetus for increased coastal climate change adaptation.

6.3 Reflections on Research Approach

There has already been a significant amount of research undertaken related to the strengths and weaknesses of effective coastal management and climate change adaptation in coastal areas in Ireland and California. This thesis will complement this existing research and add further insights on how Ireland can improve its coastal climate change adaptation efforts. This thesis will also to a certain extent help to understand what elements of California's climate change adaptation efforts can be replicated elsewhere. Furthermore, a similar research approach could be used to identify how other coastal jurisdictions aside California could assist Ireland with its coastal climate change adaptation process.

It is also very important to acknowledge the limitations associated with the chosen research approach. The differences in physical features of the coastline, population, governance systems and development between the Irish coast and the Californian coast made it at times difficult to identify suitable lessons for Ireland. In addition, the large amount of activity and evolving nature of coastal climate change adaptation in California, also proved to be challenging with finding suitable best management practices for coastal climate change adaptation in Ireland. While the Ladder of Adaptation proved to be a useful tool for comprehending and evaluating coastal climate change adaptation, it became clear during the analysis phase that the framework does not cover the wide range of activities related to

adaptation. The Ladder does not adequately address how to engage with members of the public or other key stakeholders who will be exposed to coastal climate risk. Furthermore, the ladder does not address the concept of adaptive management and the economic and social assessments of different adaptation options. Another limitation which emerged is with the whole concept of adaptation. The many barriers which Ireland and California are facing with regards to implementing adaptation highlights that perhaps adaptation as a paradigm is not working and there is the need for a paradigm shift to prepare for the impacts of climate change in coastal areas. The formalisation of coastal resiliency measures could be an alternative method of preparing for the predicted severe coastal climate risks.

7 Conclusion

The overall purpose of this thesis was to understand why and how California can help Ireland to progress with its climate change adaptation efforts. This thesis has found that Ireland faces many physical and socio-economic challenges related to coastal climate risk as well political obstacle for effective coastal climate change adaptation. In order to overcome these challenges, this thesis has also pointed out specific lessons through which California can assist Ireland with its coastal climate change adaptation efforts.

As an island nation situated in the North Atlantic Ocean, Ireland's coasts will be particularly susceptible to the impacts of climate change. Additionally, Ireland has concentrated its major urban centres, economic sectors and social infrastructure in coastal areas, which all will be vulnerable to effects of climate change. Ireland's physical and socio-economic coastal risks are compounded by an absence of a clear coastal management policy, the use of hard engineering coastal protection infrastructure, lack of coastal monitoring and a national climate change adaptation framework which does not equip Ireland adequately for the impacts of climate change. However, Ireland has a high adaptive capacity with an established economy and political system, an active coastal, marine and climate change science network as well as strong spirited coastal communities. There are limited reasons why Ireland cannot satisfactorily address the impacts of climate change in coastal areas. The serious storms and coastal flooding of 2013-2014 have raised a lot attention in the media about the risks which climate change poses in coastal areas and this has definitely created a mood for change.

As Ireland advances with preparations for the impacts of climate change in coastal areas, it can learn a lot from California's experience of adaptation. California has many similar physical and socio-economic coastal climate risks as Ireland and California has been widely regarded as a leader in addressing them. California has integrated its coastal climate change adaptation efforts into its established and successful Coastal Act. State and Federal agencies are funding projects to prepare coastal communities and ecosystems for the impacts of climate change. California has made a concerted effort, at multiple levels, to engage large sectors of the public into the coastal adaptation process in order to not only to inform them about the risks, but also to gather their support coastal adaptation measures. There are several locations throughout California where natural coastal protection projects are being initiated and assessments are being made as to what extent such projects might protect the coastline. Federal and state agencies, non-profits and research institutions are actively undertaking research to identify coastal vulnerabilities to climate change and to devise guidelines and tools to assist coastal communities to prepare for the impacts. California is also trying to ensure that key stakeholders, who will be affected by the impacts of climate change, work together. Although California has made significant progress in terms of coastal climate change adaptation, there are still many areas which are hampering California's progress including: budgetary and resource constraints, a plethora of coastal development and infrastructure and other competing environmental problems.

The comprehensive and highly integrated approach to coastal climate change that California is undertaking is something which Ireland could easily emulate. Furthermore, California's use of multi-benefit outcomes, creativity and imagination are less pragmatic but highly beneficial considerations which Ireland could incorporate into its coastal adaptation efforts. The positive approach which California is taking is a major take home lesson for Ireland. Ireland should perceive coastal climate change adaptation not as a threat but as a major opportunity to

harness the economic opportunities associated with coastal climate risks, put climate issues on the political agenda, engage coastal communities into the adaptation process and encourage research on how to understand and respond to the threats. In comparison with California, Ireland is a small island nation and there is no reason why Ireland cannot become a leader in terms of coastal climate change adaptation.

In terms of future research, although California can offer Ireland many valuable lessons, perhaps it may also be of interest to undertake research on climate on how states on the East Coast of the United States could enlighten Ireland's coastal adaptation efforts (Georgetown Climate Centre 2015). There are many coastal communities on the east coast which will be vulnerable to the effect of SLR and extreme weather events as was demonstrated by Hurricane Sandy (Georgetown Climate Centre 2015). Eastern Coastal states such as Delaware and North Carolina have also been highly proactive in devising innovative climate change adaptation strategies (Georgetown Climate Centre 2015). Furthermore, while this thesis has added to the existing research related to the main physical and socio-economic vulnerabilities related to climate change in Irish coastal areas and the major policy barriers for effective coastal climate change adaptation in Ireland, further analysis should be undertaken on the opportunities which coastal climate risks can offer Ireland.

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Appendix 1.

List of Interview Participants

Organisaton	Number of Interview Participants
National University of Ireland, Galway	2
CMRC	1
An Bord Pleanala (Irish Planning Board)	1
BCDC	1
CCC	2
SCC	1
Centre for Blue Economy, Middlebury Institute of International Affairs at Monterey	2
Center for Ocean Solutions, Stanford University	2