



## Treball de fi de màster

Títol:

*Applying quantitative methods to the analysis of coastal risk governance and perception in Catalonia*

Cognoms: Julià i Verdaguer

Nom: Anna

Titulació: Màster en Ciència i Tecnologia de la Sostenibilitat

Directora: Elisabet Roca Bosch / Co-Director: Martí Rosas Casals

Data de lectura: 01/07/2016



UNIVERSITAT POLITÈCNICA DE CATALUNYA  
BARCELONATECH

Institut Universitari de Recerca en Ciència  
i Tecnologies de la Sostenibilitat



Universitat Politècnica de Catalunya  
Institut de Sostenibilitat

Master's Degree Thesis

# Applying quantitative methods to the analysis of coastal risk governance and perception in Catalonia

Anna Julià Verdaguer

Advisor: Elisabet Roca Bosch<sup>1</sup>  
Co-advisor: Martí Rosas Casals<sup>2</sup>

1. University Research Institute for Sustainability Science And Technology- UPC
2. Sustainability Measurement and Modeling Lab. - UPC



# Abstract

**Key words:** Coastal risk, Planning, Management strategies, Governance, Risk perception, Network analysis, Policy-making, Catalonia

Risks affecting coasts can be aggravated by climate change. Having adequate response mechanisms requires an integrated, multi-risk planning system, which should include from prevention to emergency phases of risk management, together with a wide range of authorities. This research aims at analyzing the social dimension of coastal risk management at two different levels – analysis of risk governance and of local risk perception –; introducing quantitative methods as the main tool of analysis.

The approach of the research combines: (a) network analysis to draw relationships between competent stakeholders and plans, in prevention and in emergency phases, as well as to evaluate the level of integration of climate change into the current planning system; and (b) statistical analysis of a survey applied to key stakeholders to analyze the social perception at the local level. The use of unipartite graph models is introduced as a methodological innovation to visualize and analyze heterogeneous data. Quantitative methods are complemented by qualitative techniques such as planning analysis, secondary-documents review and semi-structured interviews to key stakeholders.

Results from network analysis show the complexity of the legal and administrative framework of the Catalan coastal risk planning, which partly reflects the diversity of causes, origins, temporal and spatial scales characterizing hazards and risks. On the other hand, a dissimilar management tradition depending on each type of risk is observed. Flood risk management is coordinated by local and regional administration institutions with a more multi-risk perspective but unfortunately, they are not responsible for coastal erosion, a significant component of the global coastal risk in the Catalan littoral, which is managed from a higher administrative level. In turn, climate change is not present in the emergency phase: it is only explicitly considered in the Spanish Coastal Law and the Strategic Environmental Assessment.

Concerning local perception, outcomes from the survey applied in two study areas (Maresme and Alt Empordà) reveal the impact of the geographic context to risk perception and to the prioritization of quotidian concerns. The cohabitation for decades with natural hazards in coastal areas (especially in the case of Maresme) has led the population to acquire knowledge about the origin of these problems quite in line with scientific research. In contrast, confidence towards responsible stakeholders and management tools do not present differences according to the area. Scientists arise as the most trustworthy institution, and planning and coordination are the most prioritized management strategy. It is believed that answers from this part respond to ideological criteria more than geographical context, though further research would be required to confirm this assumption. In a few words, we argue that an overall planning system that guarantees integration amongst administrative levels and sectorial policies is required to increase overall coastal safety. In addition, public perception is a core issue in risk decisions, thus its inclusion into the design of risk planning is essential to achieve an integrated strategic coastal risk management.



# Resum

**Paraules clau:** Risc costaner, Planejament, Estratègies de gestió, Governança, Percepció del risc, Anàlisi de xarxes, Presa de decisions, Catalunya

Els riscos que afecten les costes es poden veure agreujats pel canvi climàtic. Per tal de disposar de mecanismes de resposta adequats, es requereix un sistema de planejament integrat i multi-risc, que inclogui totes les fases de la gestió del risc, des de la prevenció fins a l'emergència, així com un ampli ventall d'autoritats. L'objectiu d'aquest treball és analitzar la dimensió social de la gestió del risc costaner a dos nivells diferents – anàlisi de la governança del risc, i de la percepció local del risc –; introduint mètodes quantitativs com a principal eina d'anàlisi.

L'enfocament d'aquesta investigació combina: (a) anàlisi de xarxes per dibuixar les relacions entre els actors i plans competents de la gestió en les fases de prevenció i d'emergència, així com per avaluar el nivell d'integració del canvi climàtic en el sistema de planificació actual; i (b) anàlisi estadístic d'una enquesta destinada a actors clau, per analitzar la percepció social del risc a nivell local. L'ús de models de grafs unipartits s'introdueix en aquest estudi com a innovació metodològica per visualitzar i analitzar dades heterogènies. Aquests mètodes quantitativs es complementen amb tècniques qualitatives com l'anàlisi del planejament, revisió de literatura relacionada i entrevistes semiestructurades a actors claus.

Els resultats de l'anàlisi de xarxes mostren la complexitat del marc jurídic i administratiu del planejament català del risc costaner que, en part, reflecteix la diversitat de causes, orígens i escales temporals i espacials en la caracterització de riscos. Per altra banda, s'ha observat una gestió desglossada per cada tipus de risc, convertint la gestió tradicional en desigual. La gestió del risc d'inundació es coordina des d'institucions de l'administració local i regional amb una perspectiva més multi-risc. Malauradament, però, aquestes mateixes institucions no són responsables de l'erosió costanera, una component significativa en el global del risc costaner al litoral català, que es gestiona des d'un nivell administratiu superior. Al seu torn, el canvi climàtic no està present en la fase d'emergència: de fet, només se'n fa una referència explícita en la Llei de Costes espanyola i a l'Avaluació Ambiental Estratègica.

Referent a la percepció local, els resultats de l'enquesta aplicada en dues àrees d'estudi (Maresme i Alt Empordà) revelen l'impacte del context geogràfic en la percepció del risc i en la prioritització de les problemàtiques quotidianes. La convivència durant dècades amb riscos naturals en les àrees costaneres (especialment en el cas del Maresme) ha propiciat que la població adquireixi uns coneixements sobre l'origen d'aquests problemes força en línia amb la recerca científica. A diferència de la percepció del risc, la confiança envers actors i eines de gestió no presenten diferències segons la regió. Els científics s'erigeixen com la institució més fiable, i la planificació i coordinació com l'estratègia de gestió més prioritària. S'intueix que les respostes d'aquesta part responen més a criteris ideològics que al context geogràfic, tot i que per confirmar aquesta suposició caldria més recerca. En conclusió, creiem que és necessari un sistema de planificació general que garanteixi la integració entre els diferents nivells administratius i les polítiques sectorials, per tal d'incrementar la seguretat costanera global. A més, la percepció social és un aspecte central en la presa de decisions sobre riscos, de tal manera que la seva inclusió en el disseny del planejament del risc és essencial per aconseguir una gestió del risc costaner estratègica i integrada.





# Resumen

**Palabras clave:** Riesgo costero, Planeamiento, Estrategias de gestión, Gobernanza, Análisis de redes, Toma de decisiones, Cataluña

Los riesgos que afectan las costas se pueden ver agravados por el cambio climático. Para disponer de mecanismos de respuesta adecuados, se requiere un sistema de planeamiento integrado y multi-riesgo, que incluya todas las fases de la gestión del riesgo, desde la prevención hasta la emergencia, así como un amplio abanico de autoridades. El objetivo de este trabajo es analizar la dimensión social de la gestión del riesgo costero en dos niveles distintos – análisis de la gobernanza del riesgo, y de la percepción local del riesgo –; introduciendo métodos cuantitativos como principal herramienta de análisis.

El enfoque de esta investigación combina: (a) análisis de redes para dibujar las relaciones entre los actores y planes competentes de la gestión en las fases de prevención y de emergencia; y (b) análisis estadístico de una encuesta destinada a actores clave, para analizar la percepción social del riesgo a nivel local. El uso de modelos de grafos unipartitos se introduce en este estudio como innovación metodológica para visualizar y analizar dadas heterogéneas. Estos métodos cuantitativos se complementan con técnicas cualitativas como el análisis del planeamiento, revisión de literatura relacionada y entrevistas semiestructuradas a actores clave.

Los resultados del análisis de redes muestran la complejidad del marco jurídico y administrativo del planeamiento catalán del riesgo costero que, en parte, refleja la diversidad de causas, orígenes y escalas temporales y espaciales en la caracterización de riesgos. De otro lado, se ha observado una gestión desglosada para cada tipo de riesgo, convirtiendo la gestión tradicional en desigual. La gestión del riesgo de inundación se coordina desde instituciones de la administración local y regional con una perspectiva más multi-riesgo. Desgraciadamente, estas mismas instituciones no son responsables de la erosión costera, una componente significativa en el global del riesgo costero en el litoral catalán, que se gestiona desde un nivel administrativo superior. A su vez, el cambio climático no está presente en la fase de emergencia: de hecho, sólo hay una referencia explícita en la Ley de Costas española y en la Evaluación Ambiental Estratégica.

En relación a la percepción local, los resultados de la encuesta aplicada en dos áreas de estudio (Maresme y Alt Empordà) revelan el impacto del contexto geográfico en la percepción del riesgo y en la priorización de las problemáticas cotidianas. La convivencia durante décadas con riesgos naturales en las áreas costeras (especialmente en el caso del Maresme) ha propiciado que la población adquiriera unos conocimientos sobre el origen de estos problemas bastante en la línea de la investigación científica. A diferencia de la percepción del riesgo, la confianza hacia actores y herramientas de gestión no presentan diferencias según la región. Los científicos se erigen como la institución más fiable, y la planificación y coordinación como la estrategia de gestión más prioritaria. Se intuye que las respuestas de esta parte responden más a criterios ideológicos que al contexto geográfico, aunque para confirmar esta suposición haría falta más investigación.

En conclusión, creemos que es necesario un sistema de planificación general que garantice la integración entre los diferentes niveles administrativos y las políticas sectoriales, para incrementar la seguridad costera global. Adicionalmente, la percepción social es un aspecto central en la toma de decisiones sobre riesgos, con lo que su inclusión en el diseño del planeamiento del riesgo es esencial para conseguir una gestión del riesgo costero estratégica e integrada.



# Acknowledgements

With the present thesis, my master's studies on Sustainable Science and Technology come to an end. Looking back at the moment I decided to distance from my bachelor's studies on Mathematics and opt for continuing with an apparently non-related field such as sustainability, I can express my satisfaction with this decision as the master has expanded my horizons with new ideas, knowledge of projects, tools and possibilities.

Throughout these past months, there are a group of people I would like to express my gratitude to, for having played an important role (in a way or another) in the development of this research.

In the first place, I would like to mention my advisor Elisabet Roca and co-advisors Martí Rosàs and Míriam Villares and thank them for considering me to be part of this project. Without their offer, now I would probably not know anything on coastal risk management and on the use of network analysis for its study. Thanks to Elisabet for her continuous dedication, time and her will to progress on the research. Gratitude also to Míriam for her advises and to Martí for his time on Skype and for letting me know the possibilities that exist for combining mathematics and analytical tools with sustainability research. I would also like to made a special mention to professor Maribel Ortego, for consenting to spend some of her time to solve some of my doubts in statistics.

Doing a thesis also requires working on your own quite a lot of time. This time would have definitely been less good without Sabina and our countless afternoons at the library, Gloria, Marina and Paula, Vlad and his long distance support and recommendations, and especially Xavi and his inestimable support, help and advises.

In the last but not least position, I want to thank all my family and friends for being there always and giving me all their support.



# Contents

<b>List of Figures</b>	<b>iii</b>
<b>List of Tables</b>	<b>v</b>
<b>1 Introduction</b>	<b>1</b>
<b>2 Aim and objectives</b>	<b>3</b>
<b>3 Previous concepts</b>	<b>5</b>
3.1 Coastal systems and their management .....	5
3.1.1 The coast as a complex system .....	5
3.1.2 Pressures and risks .....	6
3.1.3 Coastal risk governance and management .....	7
<b>4 Context</b>	<b>9</b>
4.1 Coastal risks in Catalonia .....	9
4.1.1 Overview .....	9
4.1.2 Main risks .....	10
4.2 Risk planning framework .....	10
4.2.1 State planning .....	11
4.2.2 Harbour planning .....	12
4.2.3 Catalan planning .....	12
4.2.4 Hydrological planning .....	14
4.2.5 Marine pollution .....	14
4.2.6 Climate change: a new variable in coastal planning .....	15
4.3 Study areas .....	16
4.3.1 Alt Empordà .....	16
4.3.2 Maresme .....	17
<b>5 Methodology</b>	<b>21</b>
5.1 Network Analysis on coastal risk planning .....	21
5.1.1 Previous notions .....	21
5.1.2 Application to assess Catalan Coastal Risk Planning .....	25
5.2 Risk perception survey .....	27
5.2.1 General characteristics of the survey .....	28
5.2.2 Statistical Analysis .....	29
<b>6 Results</b>	<b>31</b>
6.1 Network analysis on Catalan coastal risk governance .....	31
6.1.1 Stakeholders analysis .....	31
6.1.2 Risk planning analysis .....	36

6.2	Statistical analysis on coastal risk perception .. .. .	41
6.2.1	Respondent profile .. .. .	41
6.2.2	Coastal problems and activities on the local scope .. .. .	41
6.2.3	Perception of coastal risks and their management .. .. .	44
<b>7</b>	<b>Discussion</b>	<b>53</b>
7.1	Risk planning analysis .. .. .	53
7.2	Risk perception analysis .. .. .	54
7.3	Methodological innovation .. .. .	55
<b>8</b>	<b>Conclusions</b>	<b>57</b>
	<b>References</b>	<b>59</b>

# List of Figures

4.1	Positioning map of Costa Brava (Source: Roca & Villares 2013).	16
4.2	Views of the seafronts in two municipalities of Alt Empordà (Source: Roca & Villares 2013).	17
4.3	Positioning map of Maremse (Source: <a href="http://municat.gencat.cat">municat.gencat.cat</a> ).	18
4.4	View of a section of Maremse coast (Source: <a href="http://historiesdemar.wordpress.com">historiesdemar.wordpress.com</a> ).	18
5.1	Example of a simple network.	22
5.2	Example of a weighted network and the corresponding adjacency matrix.	22
5.3	Example of a bipartite network and its projections.	25
6.1	Stakeholders connected by common risks dealt.	32
6.2	Filtered network of stakeholders connected by 3 or 4 risks in common.	33
6.3	Stakeholders connected by participation in common plans.	34
6.4	Network of stakeholders, limiting their connections to plans dealing with a certain coastal risk (Erosion and inundation).	34
6.5	Network of stakeholders, limiting their connections to plans dealing with a certain coastal risk (Sea storms and marine pollution).	35
6.6	Network of stakeholders, limiting their connections to plans dealing with a certain coastal risk (Climate change).	36
6.7	Network of plans, connected by common stakeholders.	37
6.8	Network of plans, connected by stakeholders (Erosion and inundation).	38
6.9	Network of plans, connected by stakeholders (Marine pollution and sea storms).	39
6.10	Network of plans, connected according to stakeholders: focus on climate change.	39
6.11	Distribution of respondents according to sector of representation.	41
6.12	Main environmental problems: global results.	42
6.13	Main environmental problems: disaggregated results per study area.	42
6.14	Thematic spheres: disaggregated results per area.	44
6.15	Most important coastal activities according to area of study.	44
6.16	Most important factors causing erosion.	45

6.17 Most important factors causing marine and sand pollution. . . . .	45
6.18 Most important factors causing inundations. . . . .	46
6.19 Perception of the variation on beach width. . . . .	47
6.20 Perception of variation on the frequency and intensity of river floods. . . . .	47
6.21 Perception of variation on the frequency and intensity of sea storms. . . . .	48
6.22 Average perceived impact on different elements. . . . .	49
6.23 Average degree of confidence towards different institutions. . . . .	49
6.24 Average degree of confidence towards different coastal management tools. . . . .	50
6.25 Average priority percentage of different management strategies. . . . .	51
6.26 Average priority percentage of different management strategies according to economic sector. . . . .	51



# List of Tables

3.1	The eight ICZM principles. . . . .	7
4.1	Civil protection emergency plans. . . . .	13
5.1	Extract from the original summary of relations among plans, stakeholders and risks, regarding coastal risk planning. . . . .	26
5.2	Six possible projections based on combinations among plans, stakeholders and risks. . .	27
6.1	Distribution of pairs of stakeholders according to number of risks in common. . . . .	33
6.2	Environmental problems group by thematic scope. . . . .	43



# Introduction

Coasts are some of the most valuable ecosystems on the Earth in terms of biodiversity and productivity but, at the same time as providers of ecosystem services that guarantee human development and well-being. Increasing urbanization of coastal areas, together with factors such as climate change, are aggravating both risks affecting the coast and their damaging consequences. Risk management, already a complex issue due to inherent uncertainties, multiscale dynamics and many competing interests, becomes particularly significant in coastal areas: many physical, environmental and socioeconomic components are simultaneously affected by natural and anthropogenic threats.

In the context of the Catalan littoral, multiple risks currently affecting the coast, such as beach erosion, flooding and marine pollution, can be aggravated by climate change. In combination with these risks, the coast undergoes a huge pressure from being the main attraction of tourism worldwide, transforming the beaches as an icon for contemporary tourism. In order to prevent or mitigate damaging consequences, adequate response mechanisms are necessary. These require an integrated, holistic, multi-risk planning system, which should incorporate different phases of risk management, from prevention to emergency, with the participation of a wide range of stakeholders. Hence, it is relevant to assess the vulnerability of coastal systems to different risks to provide decision-makers and other key stakeholders, information about their potential consequences.

Bearing in mind this integrated, holistic, multi-risk planning, this research aims at analyzing the statutory planning system to cope with risks affecting the Catalan coast (Northwest (NW) Mediterranean) and evaluating the level of integration of climate change, as a new variable to introduce in coastal risk planning. As a complementary aspect to take into consideration in coastal governance, risk perception is also analyzed within the local scope.

The work is encompassed within two larger frameworks. The former, PaiRisC-M (CTM2011-29808), aiming at characterizing the main components (natural and anthropogenic) contributing to the risk landscape typical of the Spanish Mediterranean coast of both natural and anthropogenic and evaluate their interactions. The latter, PaiRisClima (CGL2014-55387-R), with the general objective to evaluate the coastal risk landscape along the Catalan coast under different climate scenarios at regional scale. The scope here is applied at regional scale to gain understanding of the risks at the usual scale of coastal planning and land management processes, and afterwards the analysis is downscaled to get a more detailed view of the risk landscape in two representative regions of the Catalan littoral (Maresme and Alt Empordà) taken as study areas for coastal risk perception. The variable of climate change is studied from a normative perspective, in order to assess its level of integration into current coastal risk planning.

Beyond the limits of the project, this research also aims at introducing a methodological innovation as a supporting method for qualitative analysis, and take stock of its strengths and weaknesses. The methodology combines qualitative techniques, traditionally more used in this type of analysis, with network analysis, based on graph theory. Qualitative work has allowed the set-up of an inventory of actors and plans. On its turn, network analysis is a new perspective on analyzing

relationships among these plans and stakeholders taking part in coastal risk planning which, as a primary characteristic, is more visual and may reveal unrealized aspects.

It is in this last approach where I felt my contribution could be more profitable. Firstly, and from my point of view, having studied mathematics as my bachelor's degree, it gave me the tools and knowledge (or aptitude to certain knowledge) to be able to develop the network and the statistical analysis. In regard to knowledge, during my bachelor's we were introduced to graph theory, so I already had a basis that made it easier for me to understand the implicit theory, even introducing concepts that were totally unknown by me. Referring to tools, partly thanks to the degree on mathematics, partly because of my introduction to the work life, I was rather comfortable with manipulating analytic tools such as Excel, Visual Basic or R and visualization tools such as Gephi or NodeXL.

Besides, an increasing interest towards networks and their analysis, as well as a conviction that transdisciplinarity is necessary to face future uncertainties and develop solutions accordingly, gave me the motivation to pursue the aim of this research. I am convinced that having studied the Master's degree in Sustainability Science and Technology has broaden my horizons on knowledge and inquisitiveness in this aspect.

# Aim and objectives

The major aim of this research is to analyze the social dimension of coastal risk management at two different levels, using quantitative methods as the main tool of analysis. On the one hand, the Catalan coastal governance is assessed through the analysis of the statutory planning system and the authorities responsible to cope with natural hazards. Within these risks, climate change is in particular considered in order to evaluate its level of integration into current management. On the other hand, the local community level is focused, where social perception of hazards, impacts and management in two geographical study areas is analyzed.

In particular, following the two-level approach just mentioned, the research takes a double orientation, described in detail below as two separated objectives.

- Assess risk governance in the Catalan coast by studying existent connections among planning tools and strategies, and institutions taking part in coastal risk management, as well as determine the presence and integration of climate change. Specifically, in order to achieve this first objective, several specific objectives have been defined and followed:
  - Develop a state of the art of current coastal risk management in Catalonia.
  - Go through the corresponding graph theory and identify those key aspects for network analysis.
  - Develop and analyze complete networks on: (a) stakeholders involved in coastal risk governance; and (b) plans regulating this management.
  - Introduce climate change as a variable to study its integration into coastal planning and its normative interaction with other coastal risks.
- Analyze the risk perception on the local scope by working on two study areas (Maresme and Alt Empordà), that are relevant in the Catalan littoral for coping with several natural hazards. In order to fulfill this analysis and delve into the current governance system, different gradual subobjectives are set:
  - Examine the contexts of both study areas, especially as a way to understand their main environmental concerns.
  - Analyze the results coming from a survey on coastal risk perception, answered by key stakeholders from the two study areas.

This dual structure is maintained throughout the work, as the methodology required as well as the results obtained of each perspective are totally different. The combination of both outcomes are to define a realistic picture of current coastal risk management that, on its turn, are expected to provide guidelines to improve management and adaptation strategies to climate change.

Beyond these objectives, this research has a third important intention. Analysis of risk planning and perception is traditionally taken from an exclusively qualitative perspective. The aim here is

to introduce network analysis, with its implicit graph theory, as a method to support the qualitative approach, and examine its strengths and weaknesses. This would imply a methodological innovation in qualitative analysis.

# Previous concepts

This chapter introduces some basic notions of complex systems in order to be able to define coastal areas accordingly. In addition, these coasts are characterized in general terms to have a global perspective before immersing in the specific scope of the research.

## 3.1 Coastal systems and their management

In the present thesis, as Wong et al. (2014) refer to, the coast is considered as that including all areas near Mean Sea Level (MSL).

### 3.1.1 The coast as a complex system

Many perspectives can be taken in order to define what the *coast* is, such as administrative, geographical, biological or geomorphological. However, rather than taking one of them, there is a need for a holistic outlook of the coast. Consequently, providing a broader definition is required in order to integrate all these disciplines, as well as to combine both social and ecological dimensions (Roca 2008). On this broader perspective, the coast is seen as an open system where living communities, the environment and humans interact and function as a large unit. Thus, it becomes a complex structure, with very interrelated elements and a dynamic character (Roca 2008).

This approach coincides with the general theory on systems and complexity. Page (2011) defines a *complex system* as a set of "diverse entities that interact in a network or contact structure -a geographic space, a computer network, or a market". Besides, these entities' actions are inter-dependent (Page 2011). A complex system can also be defined as that formed by a number of components, with some more intense relationships among sub-systems and which do not present linear evolution. Complex systems are large aggregations of many smaller interacting parts, they are multidimensional, which means that they are formed by hierarchical structures with different organizational levels which are interconnected, and operate on a wide range temporal and spatial scale (Roca 2008).

Coastal systems can also be considered complex systems, inheriting all the properties of these structures. Coastal environments are open, with a continuous flow of mass, energy and information that may imply perturbations that can not be foreseen. Another property of coastal systems is their socio-ecological *resilience*, that determines the capacity to adapt and recover from shock as learning from mistakes (Roca 2008).

Plurality of perceptions and conflicting interests are another factor increasing the complexity of coastal systems. The attitudes towards the environments as well as the comprehension of the relation nature-society are numerous and varied. The different ways of perceiving this relationship bring different management strategies in coastal systems. Besides, coastal systems attract a wide

range of human activities, which imply the existence of multiple interests, often in conflict. Most of these activities are concentrated in a reduced area and they often result in severe conflicts and depletion of the coastal system's functionalities (Roca 2008).

In general, systems approaches are a significant step in advancing multi-disciplinary sustainability science (Reis, Stojanovic & Smith 2014). Hence, taking coastal areas as complex systems is a step forward on their assessment from a more holistic perspective, integrating multiple and diverse disciplines.

### 3.1.2 Pressures and risks

Coastal areas are subjected to intense and sustained pressures from a diverse range of sources (Flannery, Lynch & Cinnéide 2015). These pressures are mainly caused by climate-related drivers or human-related drivers. Their combination is what is expected to have the worst outcome, as not only are coasts projected to be exposed to increasing risks, including coastal erosion, due to climate change and sea-level rise; but the effect will be exacerbated by increasing human-induced pressures on coastal areas. Besides, climate change will interact differently with the variety of human activities and other drivers of change along coastlines of developed and developing countries (Wong, Losada, Gattuso, Hinkel, Khattabi, McInnes, Saito & Sallenger 2014). These different pressures and natural hazards can produce important economic and environmental changes: storm-induced inundation and erosion are very frequent along coasts worldwide (Bosom & Jimenez 2011).

#### Climate-related drivers

Changes in the patterns of climate lead to variations on the sea level, storms, winds, waves, etc., which, in turn, impact the coastal physical environment. On shorter time scales, physical coastal impacts such as inundation, erosion, and coastal flooding arise from severe storm-induced surges, wave overtopping, and rainfall runoff. On longer time scales, wind and wave climate change can cause changes in sediment transport at the coast and associated changes in erosion or accretion. Natural modes of climate variability, which can affect severe storm behavior and wind and wave climate, may also undergo anthropogenic changes in the future (Wong et al. 2014).

#### Human-related drivers

From an utilitarian perspective, coastal systems provide a set of ecosystems that guarantee human development and wellbeing (Roca 2008), that is mainly socioeconomic development. Coasts host many of the world's major centers of commerce and they represent highly desirable locations for residential, recreational and tourism related activities (Flannery et al. 2015). As stated in the fifth IPCC assessment report, owing to their aesthetic qualities, beaches, barriers, and sand dunes, coasts are highly valued for recreation and residences (Wong et al. 2014).

The rapid development of coastal areas, since there is a global migration of people from rural areas to coastal urban centres (Gibbs 2015), is leading to a parallel increase in the population vulnerable to coastal hazards (Flannery et al. 2015). Further, the forecast of a continuing population growth as well as more obvious impacts of climate change, are likely to exacerbate the vulnerability of coastal communities. Coastal population growth, urbanization and expanding coastal tourism increase pressure on coastal environments, resulting in ecosystem degradation. This degradation reduces the long-term resilience of coastal systems and increases the vulnerability of local inhabitants to coastal hazards (Flannery et al. 2015).

In a few words, the coastal zone is particularly vulnerable and exposed to slow-changing climatic variables (Gibbs 2015): coastal ecosystems are experiencing large cumulative impacts caused by



natural and anthropogenic drivers that interact among them (Wong et al. 2014). The capacity of these systems to adapt and recover from variations depends on their socio-ecological resilience.

Resilience, a term coming from ecology, is defined by Rockström and Klum (2012) as the capacity of a system to absorb disturbance while maintaining essentially the same function, structure, identity and feedbacks. In other words, resilience gives us the capacity to deal with change while continuing to develop (Rockström & Klum 2012). In particular, socio-ecological resilience is similar to ecological, economic and social sustainability. The greater the capacity of the institutions and societies to adapt to disturbances, the less vulnerable are the ecosystems. When a system loses resilience, it also loses the ability to deal with surprises and, therefore, becomes more vulnerable to unexpected changes and perturbations. Thus, *vulnerability* is considered the opposite of resilience (Roca 2008).

Within the PaiRisClima and PaiRisC-M projects, the concept of coastal risk landscape is used to define all risks to which coastal areas are exposed and that require a systemic approach to their characterization in terms of identifying phenomena and their impacts and mechanisms of action, feedback loops and stakeholder perceptions (Roca, Villares, Oroval & Gabarró 2014a).

### 3.1.3 Coastal risk governance and management

For everything aforementioned, one can already get a clear impression about the difficulties of governing coastal systems. Risk management in general is a complex issue due to inherent uncertainties, multiscale dynamics and many competing interests. In coastal areas, the issue is especially relevant as many physical, environmental and socioeconomic components are simultaneously affected by natural and anthropogenic threats (Roca et al. 2014a).

A need for an integrated and strategic approach to the management of the coastal zone gained importance in Europe since 1999 (Ballinger, Pickaver, Lymbery & Ferreria 2010), as the relevance of including hazards and vulnerability assessments in coastal zone policies was highlighted (Bosom & Jimenez 2011). This led the European Union to position itself towards the implementation of Integrated Coastal Zone Management (ICZM) in order to deal with the complexity of coastal risks. ICZM is based on eight key principles (Ballinger et al. 2010), presented below on Table 3.1.

Principle	Brief description
Broad holistic approach	Consideration of a broader scope, broader geographical context and linkages with other planning and policy processes.
Long-term perspective	Reference to long-term processes and trends, as well as the availability of long-term data sets.
Local specificity	Consideration of the local scope: stakeholders, characteristics, concerns and information.
Working with natural processes	Inclusion of aims, policies and actions related to different natural resource aspects, such as nature conservation.
Adaptive management	Adaptive approaches to evaluate and review procedures.
A combination of policy and technical instruments	A range of tools and approaches are employed.
Support and involvement of all stakeholders	Wide stakeholder involvement as well as wide range of sectors implicated.
Participatory approach	Wide levels of consultation and participation with stakeholders and the general public.

Table 3.1: The eight ICZM principles.

ICZM is generally accepted as a process whereby a range of policies and decision-making structures are harmonized. The approach facilitates concerted action towards achieving sustainability goals by taking account of the interconnectedness of biophysical and socio-economic components of the coastal zone system (Reis et al. 2014).

In the present thesis, the focus of study is on the planning phase of risk management, as well as on the perceptions of different stakeholders related to the coastal zone.

When it comes to risk management, Flannery et al. (2015) believe that "it is critically important to understand how coastal risks are perceived by the public in order to design effective risk management strategies". The perception of risks that individuals have is influenced by different factors, such as their knowledge of a "risk", personal beliefs, social standards or any potential impact that might affect them (Flannery et al. 2015). Additionally, Roca et al. (2014) maintain that risk governance and social networks affect perceptions, beliefs and actions. Therefore, understanding the governance system, stakeholder relationships and perceptions regarding coastal risk landscape management is essential to improving the sustainability of coastal environments (Roca et al. 2014a).

For an effective implementation of ICZM, active involvement of a broad range of stakeholders is believed to be essential (Reis et al. 2014). Ideally, stakeholders taking part on coastal risk management should develop this integrated and sustainable management of coastal areas, facilitating the communication among working groups and departments. Pahl-Wostl (2009) refers to these independent but coordinated governance groups as *polycentric systems*, characterized by a nested hierarchy when it comes to decision making authority. Polycentric systems are assumed to have a higher ability to adapt to a changing environment and therefore be less affected by sudden variations (Pahl-Wostl 2009).

In order to analyze the complexity of coastal risk governance and the interaction among stakeholders implicated, quantitative methods such as network analysis resulting from graph theory as well as statistics are used. Further explanation on how these methods are developed follows on the methodology (Chapter 5).

# 4

## Context

This chapter provides an overview of the context of this research, from a geographical perspective of the coastal area studied (Catalonia), and also from a normative point of view with a descriptive summary of the current statutory planning system.

### 4.1 Coastal risks in Catalonia

#### 4.1.1 Overview

Catalonia is an area with a coastline of nearly 600 kilometers, comprising a large diversity of coastal types such as cliffs, bay beaches, long straight beaches and deltas, of which approximately one third, 192 km, is coast undergoing erosion (Bosom & Jimenez 2011, Guillén 2008). Indeed, over 70% of the 7.5 million inhabitants of Catalonia are living in a 20-km wide coastal corridor, so pressure on the coastal fabric is clearly great (Roca et al. 2014a).

What determines the vulnerability of this coast? On the one hand, the Catalan coast presents an important morphological diversity, that implies the participation of many different stakeholders, as well constant and diverse interventions all along it. On the other hand, the littoral suffers from a high level of urbanization, and the few natural resources that remain are being mortgaged and the coast is under pressure from human activities and uses (Roca et al. 2014a). Tourism, as one of the main economic driving forces of the Catalan coast, is clearly another determinant factor of this pressure. It is important to emphasize that 152 km of the coast are occupied by infrastructures and artificial beaches, and that this urbanization is likely to continue growing on the upcoming years (Guillén 2008).

The coast is also under pressure from natural phenomena requiring significant management efforts, specially from storm surges, rising sea levels and erosion (Sánchez-Arcilla, Mösso, Sierra & Prat 2012). Indeed, flooding, as a direct consequence, is the most harmful natural hazard in Catalonia, though the impact is not equal on every kilometer of the seafront. The diversity of the coast makes it possible to identify different levels of riskiness: highly dangerous areas, such as important river mouths or Barcelona; average ones, like highly urbanized areas and sandy coast; and low risky parts, such as rocky areas (Guillén 2008).

The outlook of the Catalan coast is very complex as it not only represents a physical diversity that require multiple management approaches, but it also involves an important variety of stakeholders, interventions and interests. The coordinated action of all stakeholders, mainly public entities and departments, would enhance the prevention policy of natural risks in Catalonia. As a way to analyze the structure on the coastal risk management of the Catalan coast, network analysis is carried out.

### 4.1.2 Main risks

Erosion and inundations, very frequent along coasts worldwide, are also identified as two of the most common risks in the Catalan coast and major concerns, in both the report of coastal risk in Catalonia (Guillén 2008) and the second report on climate change in Catalonia (Sánchez-Arcilla et al. 2012). Climate change forecasts point out an increase in certain risks, aggravating significantly the situation of the Catalan coast. Of special concern is the acceleration of the tendency to erosion, affecting directly certain sectors or even causing the total disappearance of other more vulnerable areas, such as Delta de l'Ebre (Guillén 2008). In this situation, assessment of damage and of impact on human activities is still not developed enough, unlike scientific understanding of these natural phenomena which is growing (Roca et al. 2014a).

Studies on climate change reflect that extreme events, such as flooding or severe storms, are likely to become more important and more frequent, causing material damage, population displacement and adverse effects on food production and availability of fresh water. Even from an economic perspective, the effects of climate change are expected to get obvious on the Catalan coast: tourism is a driving force for the economy of the local municipalities and climate is a key element for tourism. Thus, variations on the climate would make an important impact on this sector (Sánchez-Arcilla et al. 2012).

The rising of the MSL is an important indicator of climate change, though it is not the only alteration expected due to it. Interactions with atmospheric processes may lead to variations on superficial winds which, in its turn, may considerably affect wave configuration. Changes on the characteristics of the sea swell and on storms will play a key role on determining the coastal impact of climate change.

According to the studies of Sánchez-Arcilla et al. (2012), considering the current conditions, it is expected that by 2100, the erosion of the Catalan coast will be of about 100 meters on the weakest areas (such as Delta de l'Ebre), and around 70 meters on other coastal sectors. This places the Catalan beaches on a very vulnerable position, as their width ranges from 50 to 100 meters. The considered erosion is a combination of the sea level rising with the increase of severe storms and their duration (Sánchez-Arcilla et al. 2012).

## 4.2 Risk planning framework

For everything above-mentioned, proper planning seems to be key to manage the complexity of the Catalan coast. Thus, the first step for further assessment is describing how the current planning of the Catalan littoral is.

Risk management can be divided in three stages: prediction, planning and recovery. The focus here is on the planning phase in the context of Catalan coastal risk management. From this perspective, two types of planning can be identified: planning of the **prevention** and planning of the **emergency**. In the former case, natural risks are integrated into urban planning by delimiting risky areas as well as developing and implementing sectoral policies to eliminate or minimize these risks. In the latter case, plans are reactive to unexpected and possibly dangerous situations. The aim of the emergency planning is to alleviate the effects that a risk may produce.

Planning is developed and implemented at three different governmental levels: state (central government), regional (autonomous government) and local (municipalities). Before characterizing these plans, a short description of the European regulatory framework is offered as it provides the legal basis of the current normative on the Catalan coast, analyzed in the present work.

The 5 European directives that affect coastal risk management are:

- Directive 2000/60/EC of the European Parliament of the council of 23 October 2000, establishing a framework for Community action in the field of water policy;
- Directive 2007/60/EC of the European Parliament of the council of 23 October 2007, on the assessment and management of flood risk;
- Directive 2008/56/EC of the European Parliament of the council of 17 June 2008, establishing a framework for community action in the field of marine environmental policy;
- Recommendation of the European Parliament of the council of 30 May 2002, concerning the implementation of Integrated Coastal Zone Management in Europe (EU ICZM recommendations);
- Directive 2014/89/EU of the European Parliament of the council of 23 July 2014, establishing a framework for maritime spatial planning.

The last directive on maritime spatial planning is the one in the most initial phase of implementation. All of them are the starting point of coastal risk management in the Spanish state and in Catalonia, in particular.

#### 4.2.1 State planning

##### Coastal Law (Ley de Costas (LC))

As explained further in the methodology (Chapter 5), the Coastal Law, modified in 2013, and its regulations have been included on the inventory of regulatory tools of the littoral. It is a state level law of which the aim is the protection of the maritime-terrestrial public domain, having a dual perspective: prevention and emergency. In regard to risk prevention associated with coastal natural hazards, it is of special importance to achieve a spatial planning and a regulation of the land uses of the seafront areas, so as to guarantee that a large coastal section is maintained as a free and unspoiled space.

Specific rules are set for those coastal sections that are specially vulnerable to regression, limiting their use and the consent of licenses. The law introduces a specific set of rules for those coastal sections that are undergoing a serious risk of regression. This declaration of serious regression situation implies a limitation in the use and the consent of licenses in these areas. Besides, emergency or recovery actions can be anticipated in order to intervene in case of catastrophic storms or other events.

Nevertheless, the new Coastal Law may pose an increase of the risk, as it opens the door to legalize constructions performed before the 1988 law. Additionally, according to the new legal text, large format events and festivals in the beach will be allowed, arguing a dynamization of tourism and a source of income.

Since the modification of the law in 2013, LC incorporates for the first time a forecast of climate change. Not only does it explicitly appear within the objectives of the law, but it also becomes operational when LC requires the writing of a project that should include an evaluation of the possible effects of climate change on all those areas where there is a construction planned. Despite this forecast, the law clearly prioritizes hard and rigid approaches instead of positioning towards the recovery of natural dynamics (such as sand dunes). However, it seems that effects of climate change will overflow the own provisions of LC, and it is expected that the Spanish government will approve a strategy of coastal adaptation to climate change, establishing measures of protection and restoration.

### **Marine Strategy on the Eastern-Balearic marine area (Estrategia Marina de la demarcación marina levantino-balear (E MAR))**

These marine strategies, denoted as E-Mar from this point, are a tool for the planning of the marine environment that, under the shelter of Directive 2008/56/CE, of 17 June 2008, establish a common action policy framework. These strategies are to become a general framework so that different sectorial and administrative policies regarding the marine environment adjust to. The adaptation of this directive to the Spanish normative system is included in the Law 41/2010, of 29 December, of Protection of Marine environment, and it defines five marine areas, among them the Eastern-Balearic.

When it comes to risks affecting the coast, the strategies only refer explicitly to contamination, with the purpose of preventing and reducing discharges to the marine environment. The final aim is to progressively eliminate marine pollution.

Climate change is not included within the scope of marine strategies, as it is considered that it can be more suitably addresses from more global policy fields.

### **Ribera Plan (Plan Ribera (PRIBE))**

Regarding marine pollution, there is Ribera Plan (PRIBE) which, with its approval under the Royal Decree 1695/2012, of 21 December 2012, brought along a Response National System towards this risk.

The plan includes a sensibility atlas of the Spanish coast, as well as a vulnerability and risk analysis of it. Together with these aspects, PRIBE also comprises the necessary logistic and management capacities to face contamination episodes of significant dimensions and intensities.

## **4.2.2 Harbour planning**

Despite the fact that LC is the framework tool for coastal protection, harbours are governed by a specific rule. At the state level, ports are regulated by the *Ley de Puertos* (state harbour law); whereas ports on the Catalan coast are managed by the Catalan *Llei de Ports* (regional law, Pla de Ports de Catalunya (PORTCAT)). Harbours on the latter case can be ruled by *Ports de Catalunya*, a public company, or by the Territory and Sustainability Department, belonging to the Catalan government.

Some of the Spanish harbours are designated as General Interest Harbours. In Catalonia, there are two of them: the ones in Barcelona and Tarragona. Harbours of this type have a Port Usage Plan (Usos Portuarios de los Puertos del Estado (UORTE)), through which actions within the harbour area are regulated (such as sand transfers and other interventions). For example, if there is a discharge of some substance inside the port limit, it is the port authority itself that takes control of the management, under the guidelines of its port usage plan.

## **4.2.3 Catalan planning**

Regional planning of risk in Catalonia encompasses both the emergency and the prevention perspectives. Accordingly, each phase of this risk planning has its own plans and regulations, further developed below.

### Emergency: Civil Protection planning

Law 4/1997, of 20 May, of civil protection in Catalonia take into account three different types of plans: **territorial**, depending on the geographical scope to regulate; **special**, depending on sectors; and **autoprotection**, referring to private activities. It is important to highlight that none of the plans included in this emergency section are specifically related to the coast as a territorial area itself.

Firstly, territorial plans anticipate to general emergencies in Catalonia and its municipalities. There are mainly two plans involved: plan of civil protection in Catalonia (Pla territorial de protecció civil de Catalunya (PROCICAT)) and plans of municipal civil protection (Plans d'Actuació d'Emergència Municipal (PAEM)).

PROCICAT is a multi-risk plan that can be applied as a complementary tool to manage risks or emergencies that are not included in the special plans and that, at the same time, can affect a significant amount of people or have an important repercussion. PROCICAT makes no reference to climate change. In turn, PAEM are also multi-risk emergency plans but taking the municipal scope. In fact, PAEMs derive from PROCICAT and it is this latter plan that, according to risk analysis, determines which municipalities in Catalonia have to elaborate these local civil protection plans. Municipalities surpassing 20.000 inhabitants, having the consideration as touristic or considered of special risk due to its geographical situation or industrial activity, have to develop PAEM.

Secondly, sectorial plans of civil protection in Catalonia that involve the coast are Pla especial d'emergències per contaminació de les aigües marines a Catalunya (CAMCAT) and Pla d'emergència especial per inundacions de Catalunya (INUNCAT). While specific risks that can be assessed (such as flooding) are considered in these plans, those risks that cannot be appraised (for example, the wind) are incorporated in PROCICAT. These special plans may oblige to develop and approve corresponding plans at the municipal level: Programa d'Actuació Municipal (PAM).

Finally, autoprotection plans (Pla d'Autoprotecció Municipal (PAUT)) are expected for specific companies or facilities. The aim of these instruments is to regulate possible emergencies that may arise as a consequence of a private activity, as well as to establish response measures in case of risky or catastrophic public situations that could affect them.

In Table 4.1, all aforementioned plans are summarized. It is common that all these planning tools coexist but with a lack of coordination. Planning happens at different institutional levels, so it is of special importance to establish mechanisms of coordination and relation among them and their principals.

Institution	Territorial (multirisk)	Sectorial (single risk)
Catalan Government	PROCICAT	CAMCAT INUNCAT
City council	PAEM	PAM
Private	Autoprotection plans (PAUT)	

Table 4.1: Civil protection emergency plans.

### Prevention: urban planning and territory

Prevention through inclusion of risk in urban planning of a territory should be one of the main mechanisms of coastal risk planning in order to achieve an integrated management. In the case of Catalonia, the corresponding departments of the government as well as city councils would be key stakeholders of this planning.

Though, up to the present, integral prevention of risks is still not included in spatial planning, some steps have been taken forward. With the urban planning Law 2/2002, of 14 March, the Catalan Parliament included a specific prohibition in order not to urbanize or build in flood plains or in risky areas for people's safety. Besides, when it comes to urban planning, it is compulsory to incorporate a map on potential natural risks of the area planned.

The institution responsible for spatial planning is Direcció General d'Ordenació del Territori i Urbanisme (DGOTU), that ensures the coherence, equilibrium and sustainability of the Catalan territory. However, among the standards that are the base of this planning, there is no direct mention to natural risks. It is through Strategic Environmental Assessment (SEA) that these plans ensure that population, infrastructures and other settlements are not exposed to new risks.

When it comes to the protection of the seafront, the Catalan government developed a notable initiative by the negotiation and approval of directive plans for the coastal system (Plans directors del sistema costaner (PDUSC)). These plans guarantee the designation of the coastal land as not for building, basically of those lands on the beachfront that are still not urbanized.

Finally, on the prevention of risks through local urban planning, it is important to highlight the municipal spatial planning Pla d'Ordenació Urbanística Municipal (POUM), specific to each municipality (Legislative decree 1/2010, of 3 August, through which urban planning directives are approved). These plans state that entities responsible for urban planning have to ensure an appropriate quality of life, environmental sustainability, as well as environmental preservation in case of natural and technological risks. Furthermore, POUM also establishes the prohibition of building on areas liable to be flooded, as to guarantee the safety and comfort of people.

#### 4.2.4 Hydrological planning

Within this approach, there are two outstanding plans: a first one centered on the hydrological planning of river Ebre (Plan Hidrológico del Ebro (PHE)) that, consequently, is considered in the state level planning; and a second one focused on the management of drainage basins in Catalonia (Pla de gestió del districte de conca fluvial de Catalunya (PGDCFC)). Both plans take an integral perspective of risks and include environmental actions as well as interventions against erosion and storm-induced inundation.

Though being developed independently, plans on management of inundation become part of the hydrological planning. They include inundation plans for coastal areas, but they do not include possible scenarios on climate change.

A wide and diverse range of stakeholders converge on general hydrological planning. With regard to risks, institutions such as the Catalan Water Agency (Agència Catalana de l'Aigua (ACA)), Civil Protection, city councils and the general coastal management of the Spanish government (Dirección General de Sostenibilidad de la Costa y el Mar (DGC)) stand out.

#### 4.2.5 Marine pollution

Marine pollution is managed from a strategical point of view (whether in the Catalan level, through CAMCAT; or in the state level, by PRIBE), but focused on the emergency stage. These plans are competent of the management when an emergency of pollution in the marine environment occurs coming from fix focus (marine sewage pipes or other marine facilities) or mobile focus (transportation of hazardous goods), but it does not refer to emitting focus coming from land or diffused pollution. These other origins of pollution are regulated through sectorial normative (discharge of industrial water, use of fertilizers in agriculture, etc.).



#### 4.2.6 Climate change: a new variable in coastal planning

With the introduction of climate change as an aggravating variable for coastal risks, two plans began to be developed, one at the state level and another at the Catalan level.

##### **National Plan of Adaptation to Climate Change (Plan Nacional de Adaptación al Cambio Climático (PNACC))**

The Spanish ministry of Agriculture, Food and Environment is responsible for PNACC, which is on its third phase of work and it is projected for the period 2014-2020. Deriving from this national plan comes a study on climate change on the Spanish coast, carried out by the University of Cantabria (2014). In this study, effects of climate change on the Spanish coast are detected and explained in detail. It also comprises several mechanisms for managers to integrate these effects in the policies and measures for coastal protection.

The outcomes of this project are the basis to elaborate the "Strategy for adaptation of the coast to climate change effects", denoted as Estrategia de Adaptación al Cambio Climático de la Costa Española (EACCC), under the Law 2/2013, of 29 May, of protection and sustainable use of coastal areas, and the modification of the Law 22/1988, of 28 July, of coasts (LC). Currently, the strategy is on the SEA stage.

##### **Catalan Strategy of Adaptation to Climate Change (Estratègia Catalana d'Adaptació al Canvi Climàtic (ESCACC))**

In the Catalan scope, and with a time frame set by 2013-2020, this strategy suggests measures that, without explicitly referring to the coast, affect different sectors linked somehow to the littoral: agriculture, tourism, fishing, etc. In regard to coastal risk management, the strategy just requests the development of Sectorial Action Plans, that must be driven by the corresponding governmental departments and must include the private sector as well as the public administration. Mainly, these plans should set the most imperative tools and measures in order to achieve the goals established in the strategy by 2020.

The Catalan Office for Climate Change (Oficina Catalana del Canvi climàtic (OCC)) is the organization promoting and carrying out this strategy.

Bearing these two strategies in mind, one could wonder how climate change is integrated into the normative framework. On the one hand, according to PNACC, this integration has been progressively developing through sectorial regulations such as SEA, spatial planning of coastal areas (which is nonexistent in Catalonia) or planning of water resources. On the other hand, from ESCACC's point of view, integration of adaptation to climate change into current regulations is a complex process, as every sectorial planning responds to goals that not necessarily incorporate the climatic variable. Both strategies, PNACC and ESCACC, identify SEA as one of the tools that, in the short term, makes possible to incorporate adaptation to climate change into planning and sectorial programs.

Climate change is not considered neither in the territorial nor sectorial plans of civil protection. Different from those, in partial territorial plans, risks coming from climate change are integrated into building land classification. Besides, these plans also suggest adaptation measures to potential effects of climate change. In some cases, no intervention is the measure recommended (as a way of accepting the rise on the sea level and the loss of coastal areas); whereas in other situations, hard measures, such as the construction of dikes or breakwaters, or soft measures, such as sand refillment or conservation of sand dunes, are the suggested options.

PDUSCs, as land protection plans, become a propitious policy in line with climate change predictions.

## 4.3 Study areas

In order to get a closer perspective of coastal risks in Catalonia, two especially vulnerable areas in the Catalan coast were chosen as study areas: Alt Empordà and Maresme. This local approach had a double objective: at first, to focus on a narrower scope of risk management, as it is the municipal level. Secondly, to go beyond the institutional framework of plans and stakeholders, and get a wide variety of opinions from different groups of interest (such as the touristic or the environmental-friendly sectors).

### 4.3.1 Alt Empordà

The area of Alt Empordà is situated in the north-east of Catalonia, limiting in the north with France, in the north-west with the Pyrenees and in the east with the Mediterranean Sea. Due to its location, the region has a dual landscape, combining a mountain side with the coastal front, named as Costa Brava and very well known these days for being an important touristic attraction. For this reason, though Alt Empordà is used to denote the entire first study area, the focus of the research is Costa Brava and, in particular, Roses Bay.

Costa Brava is the main affected area in Alt Empordà by coastal risks, as well as other pressures such as massive tourism. This tourism started to develop extensively in the 1960s, establishing the model of "Sun and Beach" and leading to important residential growth. Beaches and small bays are the leading attraction to a huge amount of tourists, whereas trekking trails and littoral paths are, to a lesser extent, also important.

Not only has tourism transformed the urban landscape, but it has also deeply influenced on all the occupational sectors of the area, historically based on the agricultural one (primary sector). In effect, the main driving force of current economy is tourism, as well as the consequent construction industry. However, the latter has been strongly slowed down since 2008 because of the financial recession of the sector (Roca & Villares 2013).

From an urban transformation point of view, there have been two main periods of construction booms (Roca & Villares 2013). One on the decade of the 1960s coinciding with the first important arrival of tourists to the Catalan coast. This period was characterized by ad hoc constructions with no corrective interventions. The second urban-touristic expansion was experienced at the end of 1990s and beginnings of the 21st century, when the non-control increase of building construction lead to the property bubble, that ended exploding during the financial recession.

Currently, Roses Bay (in Costa Brava) is characterized by a great urbanization rate, mainly proceeding from tourism, that concentrates on the seafront. Two examples of this urban saturation, such as the municipalities of Roses and Empuriabrava in Costa Brava, can be seen in Figure 4.2. In contrast, inland areas have developed following a low density pattern. The occupation of the

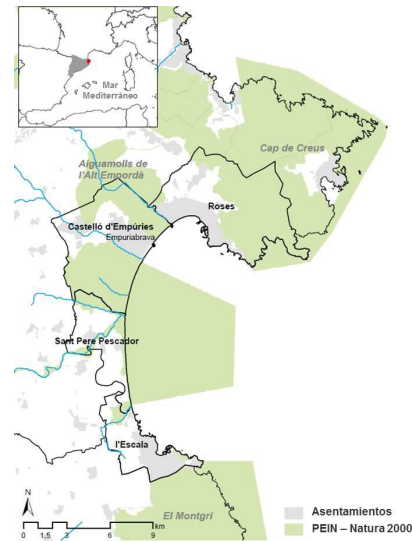


Figure 4.1: Positioning map of Costa Brava (Source: Roca & Villares 2013).

coastal area is closely linked to the development of tourism and summer residences, which have finally shape the urbanized landscape of the coast.



(a) Roses



(b) Empuriabrava

Figure 4.2: Views of the seafronts in two municipalities of Alt Empordà (Source: Roca & Villares 2013).

In its turn, the service sector has experienced a great development, thanks to the opening of more and more hotels, restaurants, campsites and other kinds of accommodation and food establishments, in order to keep up with the touristic demand.

In contrast, Alt Empordà and Costa Brava in particular also have a crucial role from an ecological perspective, with the presence of one of the last big important wetlands of the country, *Aiguamolls de l'Empordà*. The area has very rich and diverse habitats that, at the same time, shape a very fragile and complex system (Roca & Villares 2013). Due to its importance, this area was stated to be of national interest in 1983, and was finally declared National Park in 1985. But Aiguamolls de l'Empordà are not the only natural space in Alt Empordà: the Natural Park of *Cap de Creus* and the Natural Area of National Interest of *L'Albera*, among others, also provide a key ecological richness.

All these areas are especially vulnerable to coastal risks and their loss would be a total disaster for the entire area from all perspectives.

To provide a numerical context, it is surprising that the total amount of familiar houses (2011) is 116.993 when the permanent population of Alt Empordà in 2015 was of 139.838 inhabitants (IDESCAT 2016). The reason of this small difference is that only a 47% of these dwellings are of habitual residence, whereas a 45% are summer houses (the remaining percentage is of empty houses). In addition, Alt Empordà have 51.158 positions available to accommodate tourists (among hotels, campsites and rural houses). These numbers make clear the important flow of visitors in the area and their strong impact on the urban and natural landscape.

#### 4.3.2 Maresme

Maresme is a long and narrow area on the central Catalan coast, limited by the Mediterranean Sea and the hills of *Serralada Litoral*. The physical configuration of the region, as well as the proximity of Barcelona, have both had a strong influence on the development of Maresme, leading to the current urban saturation.

At the end of the nineteenth century, as a popular location for summer houses and recreational activities, Maresme experienced a first important urban development, intensified with the advent

of the railway and the construction of a rail network, which enabled people to easily shift to coastal areas.

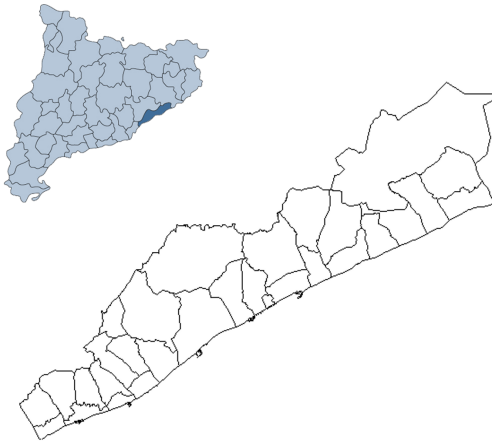


Figure 4.3: Positioning map of Maresme (Source: [municat.gencat.cat](http://municat.gencat.cat)).

However, the main urban expansion was experienced in the 1960s, especially linked to the growth of the Barcelona Metropolitan Area as well as the improvement of the public transport. Progressively, urban development shifted towards a more permanent nature (in contrast to the summer residences, initially popular), as people started searching for more affordable housing and better quality of life, in an area where services and transport options were available to maintain links with Barcelona (Roca et al. 2014a). Both urban development booms were characterized by a lack of planning, which has led to an unbalanced urban growth, inefficient on the landscape scope and unsustainable from an ecological perspective, damaging the socio-environmental development of the territory (Parcerisas 2012). The deficient planning is clearly evident by the high level of

residential growth, the disappearance of agricultural land and woods and the interference with rivers and streams, as new barriers shaped by urban and infrastructure growth increased the impermeability of the soil and blocked off almost all mountain-sea corridors (Roca et al. 2014a).

Another factor of urban saturation in Maresme is the shape of the area itself, that leaves little suitable land for agriculture or development. Even in this situation, Maresme embraces significant transport infrastructures, such as a secondary road, N-II; the railway line by the coast, that especially in summer brings crowds into the beaches; and a motorway, C-32, built further inland. The laying of the railway line in the coastal corridor led to the loss of a significant part of the beaches, but especially of the dunes that played a key role in limiting and regulating sand exchange and protecting the coast. Besides, the threat of erosion for the integrity of the railway and its operation eventually led to the construction of a parallel breakwater (Roca, Villares, Oroval & Gabarró 2014b). The presence of all these infrastructures and constructions on the seafront makes erosion especially threatening in this area. A section of the coast of Maresme especially affected by this problematic is seen in Figure 4.4, where one observe a motorway extremely close and parallel to the seafront.



Figure 4.4: View of a section of Maresme coast (Source: [historiesdemar.wordpress.com](http://historiesdemar.wordpress.com)).

With all that, the waterfront coastline has become a multifunction space, as it represents the physical basis for recreation and leisure (promenades and beaches), it develops a coastal defense role, and it accommodates a key transport infrastructure that enhance the mobility of population from other areas of Catalonia. These factors clearly pose a huge pressure on the coast, which consequently undergoes unstable dynamics. An obvious example of these uncertain dynamics is the sediment deficit, given the lack of input from rivers and streams, that results in

an ongoing loss of sand, intensified during storms (Roca et al. 2014*a*). Since 1986, timely beach replenishment operations remedy sand losses. These interventions are repeated periodically, typically at the beginning of each summer season, in order to support the recreational uses of the beaches. However, this is not a definitive solution and it only mitigates very precariously the problem. Besides, it is costly and environmentally damaging and has impacted negatively on the fishing industry (Roca et al. 2014*a*).

From a demographic perspective, Maresme has a population of 439.512 permanent inhabitants and 213.402 familiar houses. Out of this total, an important 78% are habitual residences, whereas only an 11% are secondary or summer houses (the remaining 11% corresponds to empty dwellings) (IDESCAT 2016). Indeed, it is important to mention the additional floating population of between 10% and 20% (depending on the season of the year), basically coming from the Barcelona area (Roca et al. 2014*b*).



# 5

# Methodology

Mentioned in the introduction, this research also aims at introducing a methodological innovation as a supporting method of qualitative analysis, and take stock of its strengths and weaknesses. The methodology combines qualitative techniques such as planning analysis, secondary-documents review and semi-structured interviews of experts with network analysis, based on graph theory. Qualitative work has allowed the set-up of an inventory of actors and plans, afterwards connected among them in line with their relations. Network analysis is a new perspective on analyzing these relationships among plans and stakeholders taking part in coastal risk planning. Climate change is a variable that will be included and excluded from network analysis as a way to study its presence and integration in the planning system. Nevertheless, insights coming from in-depth interviews are necessary for the interpretation of relationships among plans and stakeholders.

In this chapter, the methodology used throughout the research work is presented. In a few words, the applied methods are mainly quantitative, with the aim of using them as the backing of qualitative data already available in the project. Two separate methodologies are defined and assessed: network analysis, based on mathematical graph theory; and statistical analysis.

## 5.1 Network Analysis on coastal risk planning

A great part of graph theory behind network analysis presented below is taken from the book "Networks: An Introduction", by Mark Newman (Newman 2010).

### 5.1.1 Previous notions

*Networks* are the cornerstone of the following research, so providing a consistent basis on them is crucial in order to understand the application on the analysis of coastal risk management.

In mathematical terms, a network (also called a *graph*) is a structure formed by *vertices* (or *nodes*) that are joined by *edges* to represent their relationships. Given a graph  $G$ , it is common to denote the number of nodes as  $n$ , and the number of edges as  $m$ . There are different types of edges, such as *multiedges*, that are the collections of multiple edges that connect a same pair of vertices; or *self-edges*, which connect vertices to themselves.

In the present methodology, *simple networks* will be used. These networks are characterized for having neither self-edges nor multiedges. An example of these simple networks is seen in Figure 5.1.

Another concept to introduce is *graph density*. This is the ratio between the number of existent edges of a graph and the total number of possible edges. Given an undirected graph  $G$  with  $n$  nodes and  $m$  edges, the density is defined as

$$D = \frac{2m}{n(n-1)}, \quad (5.1)$$

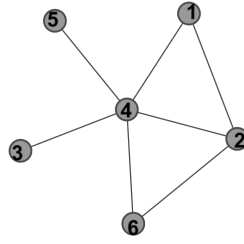


Figure 5.1: Example of a simple network.

since the maximum number of edges in a graph with  $n$  nodes is  $n(n-1)/2$ . Density  $D$  takes values between 0 and 1 ( $D \in [0, 1]$ ).

### Adjacency matrix

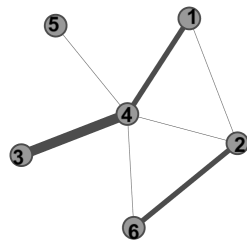
Graphs need to be characterized as a structure in mathematical terms. A suitable representation of a network is the *adjacency matrix*. Given a simple graph of  $n$  vertices, let  $\mathbf{A}$  be the corresponding  $n \times n$  adjacency matrix with elements  $A_{ij}$  such that

$$A_{ij} = \begin{cases} 1 & \text{if there is an edge between vertices } i \text{ and } j, \\ 0 & \text{otherwise.} \end{cases}$$

This results in matrices full only with zeros and ones, that are *symmetric*<sup>1</sup>, the same as saying that  $A_{ij} = A_{ji}$ , for all  $i \in \{1, \dots, n\}$  and  $j \in \{1, \dots, n\}$ . In addition, the diagonal matrix elements are all zero since there are no self-edges. Following, the adjacency matrix of the simple network in Figure 5.1 is presented.

$$A = \begin{pmatrix} 0 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 \end{pmatrix}$$

However, not all networks are so simple and may not have only simple connections among nodes. Therefore, it is useful to represent edges as having a strength or weight, in order to give them a specific value. These *weighted networks* can be represented by giving the elements of the adjacency matrix values equal to the weights of the corresponding connections.



$$A = \begin{pmatrix} 0 & 1 & 0 & 2 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 2 \\ 0 & 0 & 0 & 3 & 0 & 0 \\ 2 & 1 & 3 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 2 & 0 & 1 & 0 & 0 \end{pmatrix}$$

Figure 5.2: Example of a weighted network and the corresponding adjacency matrix.

<sup>1</sup>A *symmetric matrix* is a square matrix that satisfies that  $\mathbf{A}^\top = \mathbf{A}$ , where  $\mathbf{A}^\top$  is the transpose.



A *directed network* or *directed graph* is a network in which each edge has a direction, with a source node and a target node. These directed edges are represented as lines with arrows.

The adjacency matrix  $\mathbf{A}$  of a directed graph is slightly different. Its elements are defined as

$$A_{ij} = \begin{cases} 1 & \text{if there is an edge from vertex } j \text{ to } i, \\ 0 & \text{otherwise.} \end{cases}$$

In general, adjacency matrices of directed networks are asymmetric.

### Cocitation and bibliographic coupling

The structure of a graph characterizes the network itself and the relations among its elements. The study of a network's structure is, therefore, an important step on network analysis. One approach to this study is the use of *cocitation* or *bibliographic coupling*, two related ideas that derive from the analysis of citation networks.

*Cocitation* of two vertices  $i$  and  $j$ ,  $C_{ij}$ , in a directed network is defined as the number of vertices that have outgoing edges pointing to both nodes. In bibliographic terms, the cocitation of two papers would be the number of other papers that cite both. Given the definition of a directed network that set that the element of the adjacency matrix  $A_{ij} = 1$  if there is an edge from  $j$  to  $i$ , one can see that

$$A_{ik}A_{jk} = \begin{cases} 1 & \text{if } i \text{ and } j \text{ are both cited by } k, \\ 0 & \text{otherwise.} \end{cases}$$

Adding for all  $k$ , the cocitation  $C_{ij}$  of  $i$  and  $j$  is

$$C_{ij} = \sum_{k=1}^n A_{ik}A_{jk} = \sum_{k=1}^n A_{ik}A_{kj}^T,$$

where  $A_{kj}^T$  is an element of the transpose matrix of  $\mathbf{A}$ . The elements  $C_{ij}$  define what is known as *cocitation matrix*  $\mathbf{C}$ , given by

$$\mathbf{C} = \mathbf{A}\mathbf{A}^T.$$

The  $n \times n$  matrix  $\mathbf{C}$  is symmetric and it defines a *cocitation matrix*, with an edge between node  $i$  and  $j$  if  $C_{ij} > 0$ , for  $i \neq j$ .

The idea of bibliographic coupling is similar to cocitation, but the other way round. The *bibliographic coupling* of two vertices is defined as the number of other vertices to which both point. In bibliographic terms, the bibliographic coupling of two papers  $i$  and  $j$  is the number of other papers  $k$  that are cited by both. Using again the definition of directed networks and their adjacency matrices,

$$A_{ki}A_{kj} = \begin{cases} 1 & \text{if } i \text{ and } j \text{ both cite } k, \\ 0 & \text{otherwise.} \end{cases}$$

Thus, the bibliographic coupling of  $i$  and  $j$  is the sum for all  $k \in \{1, \dots, n\}$ :

$$B_{ij} = \sum_{k=1}^n A_{ki}A_{kj} = \sum_{k=1}^n A_{ik}^T A_{kj},$$

These elements again define the corresponding  $n \times n$  matrix, called the *bibliographic coupling matrix* and denoted as  $\mathbf{B}$ . In general terms,

$$\mathbf{B} = \mathbf{A}^T \mathbf{A}.$$

This matrix  $\mathbf{B}$  is symmetric and its elements can be used to define the *bibliographic coupling network*, a weighted undirected network in which there is an edge with weight  $B_{ij}$  between any two vertices  $i$  and  $j$  where  $B_{ij} > 0$ .

Cocitation and bibliographic coupling are measures that are mathematically similar. However, they can in practice give visible different results. Let us follow with some applications to exemplify the use of cocitation and bibliographic coupling as indicators (Newman 2010).

**Example 5.1.1** In the first case, citation networks of academic papers are a perfect depiction of cocitation networks. Strong cocitation between papers is often a good sign of papers that deal with related topics: if two papers are often cited together, it is likely that they have something in common. Further, the more often two papers are cited together, the more likely it is that they are related.

**Example 5.1.2** In the latter case, the same example of citation networks is valid. Now, the bibliographic coupling of two papers,  $i$  and  $j$ , indicate the number of other papers that are cited at the same time by  $i$  and  $j$ . Therefore, this is a good indicator on the relationship among papers: if two papers cite many of the same other papers, it is often a good measure that they deal with similar subject matter. The number of common papers cited may be a clear indicator of how strongly they overlap.

### Bipartite networks and projections

Vertices in a network may be of different types and therefore belong to different groups. In the case of two kinds of vertices, the membership of these to one or other group can be represented in a *bipartite network* or *two-mode network*. The edges in a bipartite network only join vertices of different types: given two modes of vertices,  $\mathcal{A}$  and  $\mathcal{B}$ , a node of type  $\mathcal{A}$  can only be connected to another of type  $\mathcal{B}$ , never to one of the same mode.

In a bipartite network, not all nodes can be connected to each other. Therefore, instead of an adjacency matrix, edges can be represented in a rectangular matrix called *incidence matrix*. Let  $n$  be the number of vertices of one type and  $m$  the number of the other type. Then the incidence matrix  $\mathbf{D}$  is  $n \times m$ , such that its elements  $D_{ij}$  are

$$D_{ij} = \begin{cases} 1 & \text{if } j \text{ is linked to } i \text{ of the other type,} \\ 0 & \text{otherwise.} \end{cases}$$

**Example 5.1.3** A very intuitive example of bipartite graphs is a *film network*, where actors and films (in which they appear) represent two types of vertex. In this network, each actor would be connected by an edge to each film in which he or she appeared.

Although bipartite networks give a complete representation of a particular network, it may be often more helpful to study connections between vertices of the same type. Bipartite networks can derive to *one-mode projections*, which are of particular interest for the study of the present thesis. With these projections, one can shift from a two-mode graph to a one-mode one, though losing information of the original bipartite network during the construction of the projection.

A general idea of one-mode projections is that two vertices of this mode will be connected if, on the complete bipartite graph, they are both related to the same node of the other type. The result is a network with only one "dimension" of nodes, linked according to the connections with the other mode of vertices on the original bipartite graph. A simple graphical example of bipartite networks and the corresponding one-mode projections is seen in Figure 5.3.

From a mathematical perspective, a projection can be written in terms of the matrix of incidence  $\mathbf{D}$ . Two elements  $i$  and  $j$  of one type are connected to each other in the projection if they are both linked to a node  $k$  of the other type. In that case,  $D_{ki}D_{kj} = 1$  and, therefore, the total number of elements of the other type to which  $i$  and  $j$  are connected is

$$P_{ij} = \sum_{k=1}^m D_{ki}D_{kj} = \sum_{k=1}^m D_{ik}^{\top}D_{kj}.$$

The resulting  $n \times n$  matrix  $\mathbf{P} = \mathbf{D}^\top \mathbf{D}$  is similar to an adjacency matrix for the weighted one-mode projection onto the  $n$  vertices. One difference is that the elements of the diagonal are not 0 as they are supposed to be in the assumption of a network with no self-edges. Thus, one would calculate  $\mathbf{P} = \mathbf{D}^\top \mathbf{D}$  and set the diagonal elements equal to zero in order to represent the corresponding network.

The projection to the other mode can be represented by the  $m \times m$  matrix  $\mathbf{P}' = \mathbf{D} \mathbf{D}^\top$ , whose diagonal elements are later set equal to zero to avoid self-edges.

**Example 5.1.4** Following the example on the film network, there are pairs of actors that have appeared in many films together. When projecting to the one-mode projection of actors, for example, two actors would be connected by an edge if they have taken part together in specific movies. A stronger connection indicates a higher number of common films, which makes it reasonable to suppose that these two actors have a more well-established relation.

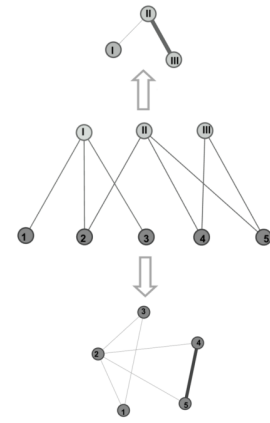


Figure 5.3: Example of a bipartite network and its projections.

### 5.1.2 Application to assess Catalan Coastal Risk Planning

All this graph theory can be applied for the analysis of coastal risk management in the Catalan littoral. In order to employ this method, it is first necessary to define which elements will perform as nodes, as well as which type of relation will be used to link vertices.

#### Starting point

As a commencement for the analysis of the coastal risk management, two inventories were developed exhaustively: one on *stakeholders* taking part on this management at some point, and another one on *plans* that regulate the coastal zone on different aspects, such as activities taking place in it or interventions in case of emergency. All normative planning that constitute regulatory tools of the littoral, possible uses of the seafront, as well as the definition of the protected areas, were listed in this second inventory, classified according to different characteristics. Non-normative plans and laws were excluded from this inventory. However, on the state level, the Coastal Law (LC) was included given its relevance, direct application and the lack of a planning tool directly derived from the law. Both stakeholders and plans are determined by the risk (or risks) that they deal with.

Bearing in mind this last consideration, and after these two inventories were developed, a summary of the existing relations among stakeholders, plans and risks was generated. This table is the cornerstone of both the development and the interpretation of network analysis, where stakeholders, plans and risks are key elements.

**Plans:** All plans explained on Section 4.2 were included for representing the basis of coastal risk planning in Catalonia. As already mentioned, plans are associated to a phase of time according to whether they are activated and followed before a risk occurs (planning of the prevention) or when it happens (planning of the emergency). Further, the planning is developed on three different administrative levels, state, autonomous governments or local authorities, according to origin of implementation.

**Stakeholders:** Actors considered for the networks are only those from the administration. Only administrative stakeholders that can be legally linked in the plans appear in the network analysis. Hence, socio-economic and environmental actors that could have participated in the

elaboration of this plans are not introduced. Stakeholders participating in this management are diverse and their involvement differs significantly due to their nature, interest, thinking, role, etc. As well as plans, stakeholders can participate on the planning of the prevention, of the emergency or on both phases.

**Risks:** Five risks are identified as potential threats to the Catalan coast: climate change, coastal and marine pollution, erosion, inundation and sea storms. Notice that climate change is treated as a separated risk, though being conscious that it is indeed a driver aggravating the four other threats to the coast. Considering it as a individual risk, the objective is to examine its degree of integration into coastal risk planning.

All plans related to coastal management and potential risks are listed on the data base. Each of them is associated to the risks it tackles, as well as to the stakeholders responsible for its proper implementation, tracking and compliance.

Following, an extract of the original data base is depicted, where EACCC is the strategic coastal adaptation planning to climate change. The principal of the plan is DGC, the coastal management office of the Spanish government, and it deals with erosion, inundation and climate change. The Spanish Office for Climate Change (Oficina Española de Cambio Climático (OECC)) appears as a secondary stakeholder.

Plan	Risk	Main stakeholder	Other stakeholders	Phase
EACCC	Erosion	DGC	OECC	Prevention
EACCC	Inundation	DGC	OECC	Prevention
EACCC	Climate change	DGC	OECC	Prevention

Table 5.1: Extract from the original summary of relations among plans, stakeholders and risks, regarding coastal risk planning.

Plans, stakeholders and risks represent three types of data that can be used as nodes in further networks, while relations among them will perform the edges.

The three-mode definition of the elements makes clear that a the resulting network has three parts, and connections are only possible between vertices of different groups, as a plan is connected to risks and stakeholders but not to other plans. It could be said that the focus of study is, therefore, a tripartite graph. However, in order to simplify the analysis, the three types will be studied in pairs and using projections. The couplings {Plans, Actors} and {Actors, Risks} arise as the most interesting for the analysis.

### Analysis of Catalan coastal risk management

The main aim of the study is to examine existing relations among elements of one same type (plans, stakeholders or risks). In order to carry out the analysis, one-mode projections are used as the main suitable tool, that nourishes from the original data base on relations among plans, stakeholders and risks (See Annex I). In effect, projections help shifting from bipartite to one-mode networks, and studying the relation among elements of one particular group.

Six different combinations were first studied in order to get those projections that were more interesting and useful for the project. These six initial projections are listed below on Table 5.2. It is important to point out that there are six possible combinations because, here, pairs of elements are not commutable: for notation, Plans-Stakeholders is the projection on plans, whereas Stakeholders-Plans is the projection on stakeholders.

Of particular interest is to examine how plans relate to each other when it comes to managing risks, as well as how stakeholders interact among them to take control of a specific situation, whether it

One-mode projection	Connections	Brief description
Plans	Stakeholders	One-mode projection on plans, connected according to common stakeholders they have.
	Risks	One-mode projection on plans, connected according to common risks they deal with.
Stakeholders	Plans	One-mode projection on stakeholders, related according to common plans they take part in.
	Risks	One-mode projection on stakeholders, connected by common risks they deal with.
Risks	Plans	One-projection on risks, connected according to plans that deal with them at the same time.
	Stakeholders	One-projection on risks, connected according to stakeholders that deal with them at the same time.

Table 5.2: Six possible projections based on combinations among plans, stakeholders and risks.

is an emergency or a preventive action. Therefore, though evaluating the six possible projections, the final focus of network analysis is on the following three pairs:

**Plans-Stakeholders:** The number and type of common stakeholders among plans partly determine how these interact to each other. The projection of stakeholders on plans enables this approach to the analysis, as the outcome is that two plans are connected if at least one stakeholder takes part on both plans. The strength of this relation is proportional to the number of stakeholders two plans share. Stakeholders are the real link of communication as they are the ones to work together when planning the prevention or the emergency phases of a risk. Thus, it is reasonable to think that the more stakeholders two plans share, the more connected they are and the more overlapping it is avoided.

**Stakeholders-Risks:** Of importance here is to study where different stakeholders focus their attention when it comes to the management of the coast. This focus is determined by the risks a particular stakeholder deal with, and so stakeholders sharing the management of the same risks will be more connected than those not having any risk in common.

**Stakeholders-Plans:** Inverse situation of plans-stakeholders. Stakeholders participating in the same plans need to work together, so their coordination is fundamental. Thus, the number and type of common plans between two stakeholders determine their closeness or distance in coastal risk planning.

Everything presented in this Section has been used in order to get to the results presented in Chapter 6.

## 5.2 Risk perception survey

The second part of the research takes a closer look on coastal risk management, focusing on the local scope. To do so, local stakeholders from two coastal areas of Catalonia were asked to answer a **survey** on social perception about coastal risks and their consequential effects coming from different natural events happening in the area, such as storms or inundations.

### 5.2.1 General characteristics of the survey

The methodology used to analyze risk perception at the local level is based on a closed questionnaire sent to key local stakeholders. These multiple chosen stakeholders are representatives of institutions, organizations or groups that are, directly or indirectly, related to risk management or affected by their impacts. Hence, respondents of the survey represent an heterogeneous group of selected people from the touristic sector, public administration, environmental and social entities, among other sectors. The aim of this diversity is to have a broad perspective of the social perception of coastal risks and their effects, as well as including different economic and territorial interests.

The questionnaire consisted of 19 closed questions of different formats: unique answer, multi-response or level of measurement according to Likert scale<sup>2</sup> 1-5. The questions were organized in four clear separated parts:

- (i) A first section, to characterize the respondent in terms of gender, age, interest sector and geographic area that represents;
- (ii) A second one, to contextualize the main problems on the local scope as well as the main activities that take place on the littoral;
- (iii) A third part, to analyze the coastal risks and its management;
- (iv) A last one, to highlight the main current uses of the coast and the desired ones, by establishing an order among "Tourism and recreation", "Protection and support to infrastructures and urban space" and "Supplier of environmental quality and landscape".

The third section, regarding coastal risks, is the most extended one, as the aim is to directly investigate about perceptions on natural phenomena that may generate risks to the coastal area under study. With every question, the intention is to focus on one different approach around these risks, from the perspective of the respondent. The main different aspects of coastal risks considered are:

- Factors causing the different events: erosion of the beaches, contamination of water and sand, and inundations;
- Evolution of these events: basically, rise or reduction of natural hazards;
- Socio-economic impact of the different events on several common elements of the coast, such as the touristic sector, harbors or the comfort of the beaches.

More than just focusing on risks and their effects, this third part of the questionnaire also focuses on the coastal risk management and the role of stakeholders involved in it. Accordingly, three of the questions are about evaluating the following items:

- Level of confidence to institutions and organizations;
- Level of confidence to different management tools and plans;
- Priority on management strategies, from investment on maritime engineering to promotion of research.

In total, 52 answers to the questionnaire were collected from the distribution of the survey that was carried out via email, during winter and spring months in 2014.

---

<sup>2</sup>A *Likert scale* is a scale of psychological measurement and the most widely used approach to scaling responses in survey research.

### 5.2.2 Statistical Analysis

The compiled data were entered in an Excel spreadsheet, as to carry out a descriptive statistical analysis of each of the questions separately. Both general and geographic desaggregated results were obtained, in order to have, on the one hand, the big picture of risk perception and, on the other hand, results of each geographic area and analyze similarities and differences between them.

This descriptive statistical analysis combined with qualitative information of the area, interviewees, etc. leads to a deeper interpretation of results, extensively developed in Chapter 6.





# 6

## Results

In this chapter, results will be presented from both the network analysis on current planning and governance of coastal risks in the Catalan littoral, and the survey on social perception of these risks in the local level.

### 6.1 Network analysis on Catalan coastal risk governance

The first aim of this thesis is to analyze how coastal risks are currently managed and coordinated in the Catalan littoral and assess how this governance could be enhanced. In order to achieve that, network analysis, with the corresponding graph theory, is used to get both the planning and the stakeholders' perspectives.

The complexity of the legal-administrative framework of coastal risk management is obvious when examining the inventories on plans and stakeholders. This complexity comes from the diverse variables that influence coastal risks: from the origin of coastal risks (sea, land or air), the spatial scale of affected area (from local to cross-borders issues), to the temporal scale of consequences (ranging from immediate until slow processes). The intricacy on coastal risk management becomes a concern when there is inefficient coordination.

Some network representation guidelines are now established to standardize all graphical results. When plans are represented, three colors are used to depict the phase of planning: **green**, for prevention planning; **red**, for emergency planning; and **blue**, for mix planning (plans that take part on both the planning of the prevention and the emergency). For stakeholders, these three same colors are used according to their participation on a certain plan on the prevention (green) or emergency (red) phases, or on both (blue).

#### 6.1.1 Stakeholders analysis

Based on one-mode projections presented in Section 5.1, a first approach to analyze risk planning is by understanding how stakeholders involved in this management relate to each other. Different perspectives could be taken to study these relations. Here, following graph theory on cocitation and coupling networks, it is defined that two stakeholders are connected if they deal with common risks, as it reveals that both entities work and make efforts along the same lines. There is a total of 13 stakeholders somehow taking part in coastal risk governance, with 5 types of risks included and already mentioned: erosion, flooding, marine pollution, sea storms and climate change. It has to be emphasized that climate change is treated as a separated risk, though being aware that it is indeed a driver aggravating erosion and flooding, or maximizing sea storm events. Proceeding in this way, the objective is to understand the degree of integration of climate change into current regulations.

It is important to recall that two classifications were used for stakeholders. In the first place, with an administrative level distribution, three different scopes were considered: state, Catalan and local levels. Secondly, an arrangement of stakeholders according to the stage of planning in which they are involved: whether they take part in the planning of prevention, emergency or both phases. This last classification is the one used to color nodes in the network: green (prevention), red (emergency), or blue (both phases).

Starting with the big picture of all stakeholders connected by all risks, the resulting network is presented in Figure 6.1. First aspect to point out is the high density of 0,91, which implies that nearly all stakeholders share at least the management of one risk with the rest. The fact that this is not a fully connected network is because of stakeholders such as OCC and Direcció General de Pesca i Afers Marítims (DGPESCA), that focus their efforts on one unique risk: climate change, in the case of OCC; and marine pollution, in the case of DGPESCA. Indeed, there are 7 pairs of stakeholders that do not share the management of any risk.

Another noticeable feature of the whole network of stakeholders is the large presence of edges with weights higher than one. This means that, bearing in mind all pairs of stakeholders, most of them share the participation in more than one risk.

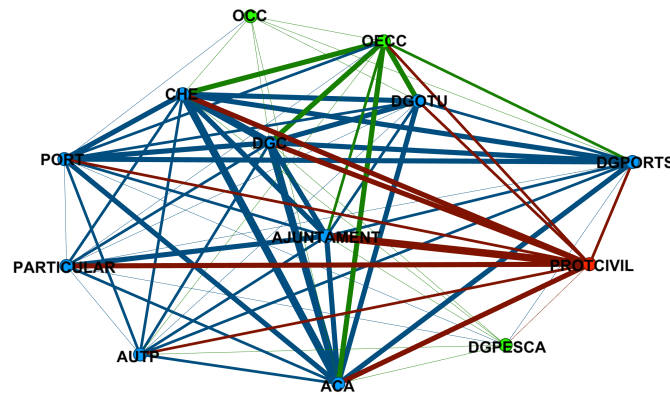


Figure 6.1: Stakeholders connected by common risks dealt.

Because of the aforementioned characteristics, the big picture of stakeholders is not clear and is indeed rather difficult to interpret. However, at the same time, the complete network of stakeholders reflect the complexity and high interconnectivity among all the natural hazards and their management. As a procedure to help clarifying and interpreting the big picture, a suitable tool here, widely used in network analysis, is the application of a filter by edge weight. Given the total number of possible pairs of stakeholders (equal to  $\frac{13 \cdot (13-1)}{2} = 78$ ), in Table 6.1, the distribution of these pairs of stakeholders according to number of risks in common is calculated. It can be observed that nearly in equal proportion, pairs of stakeholders share one, two or three risks.

Looking at the network in detail, in Figure 6.2 a filter has been applied to the complete network of stakeholders in order to obtain stakeholders taking part in the management of three or four common risks (as there is no pair of stakeholders sharing the five risks studied in the present work). Those stakeholders are believed to have similar concerns, and so their connection in reality should be stronger. Clearly, there are two outstanding subsets of stakeholders emerging as central elements of the network. In the first place, the triad formed by DGC, Confederación Hidrográfica del Ebro (CHE) and ACA, all of them involved in plans focused on marine pollution, inundation, erosion and climate change. Hydrological plans are indeed the only territorial sectorial planning with a real integrating and holistic will, trying to gather all dynamics affecting the territory into one unique plan. This partly leads to the highlighted strong interconnectivity among these three stakeholders.

Number of common risks	Number of pairs	Percentage
0	7	8,97%
1	23	29,49%
2	22	28,21%
3	22	28,21%
4	4	5,13%
5	0	0,00%
<b>Total</b>	<b>78</b>	<b>100%</b>

Table 6.1: Distribution of pairs of stakeholders according to number of risks in common.

The second outstanding subset of stakeholders is formed by the coupling city council and Protecció Civil de Catalunya (PROTCIVIL), concentrating efforts on the management of coastal risks in the emergency phase, which incorporate erosion, inundation, sea storms and marine pollution, and exclude climate change. In fact, this connection is a direct consequence of the fact that the local emergency plans PAM derive from civil protection.

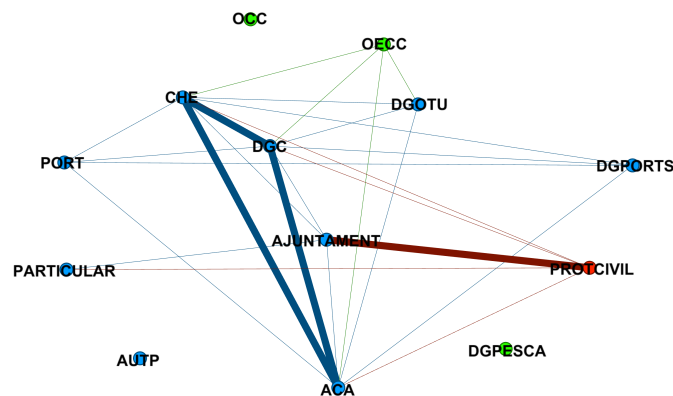


Figure 6.2: Filtered network of stakeholders connected by 3 or 4 risks in common.

In the opposite situation, there are three stakeholders that get isolated when applying the edge-weight filter: OCC, DGPESCA and Autoridad Portuaria (AUTP). As introduced before, the first two organizations only take part in the management of one risk. In addition, it is also noticeable that OCC and DGPESCA are two of the three stakeholders that are involved exclusively in the planning of prevention. The fact that they are the first ones to get disconnected from the core network is also significant when analyzing how coastal risks are currently weakly integrated into the prevention stage. On its turn, AUTP through UPORTE deals with two coastal risks: erosion and marine pollution.

Taking the complete network of stakeholders depicted in Figure 6.1 as the basis, it is possible to limit connections only among stakeholders participating in a certain risk. In other words, only establishing links between stakeholders that are related to a specific risk, though afterwards maintaining the intensity of connection according to whether they share more risks. However, this approach is not as interesting here as it will be in the following analysis, since connections among stakeholders would not change from the base network. The restriction of the network to a certain risk would facilitate visualizing which stakeholders take part in the management of this risk, though not providing more information on how they relate. Consequently, another perspective is needed in order to study relations among stakeholders dealing with a certain risk.

The new approach used here defines the connection between two stakeholders if both take part in common plans. The weight of this edge is the total number of common plans. The big picture of stakeholders connected by common plans is seen in Figure 6.3. It reveals the presence of a six-element core group, especially standing out the triad AJUNTAMENT-PARTICULAR-PROTCIVIL; a rather important role of OECC, moderately connected to the core group; and a peripheral set of stakeholders, weakly related to the rest.

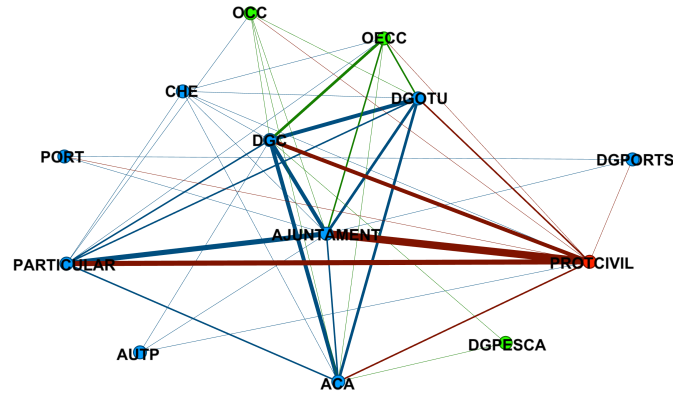
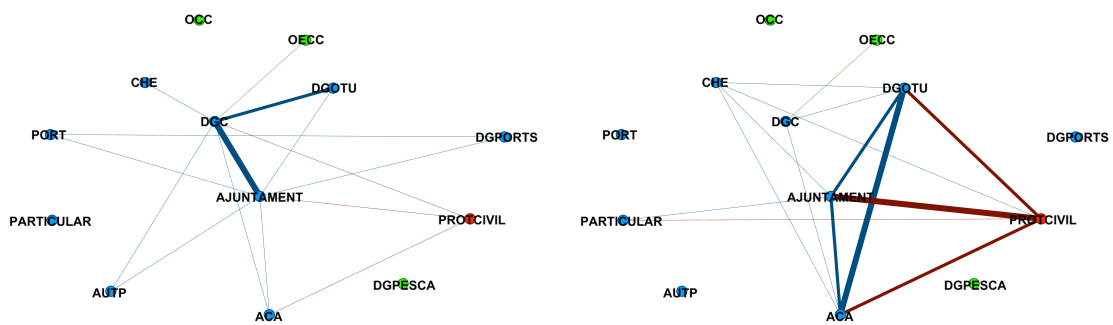


Figure 6.3: Stakeholders connected by participation in common plans.

Moving forward from the general overview of coastal risk governance that has been developed thus far, from this point the analysis is taken bit by bit. Accordingly, an interesting approach to the network analysis of stakeholders is to limit the connections to a certain risk. In other words, considering only those stakeholders and relations that deal with this specific risk to determine which stakeholders participate in the management of a certain risk and to analyze the level of coordination among them.

The first risk to be taken separately is coastal **erosion**: out of the initial 13 stakeholders, a great majority of them, 10, deal with this risk. These ten stakeholders and their connections are seen in Figure 6.4a where links between the city council (AJUNTAMENT) and DGC, and between DGC and DGOTU stand out, positioning these three stakeholders at the center of coastal erosion management.



(a) Stakeholders taking part in the management of coastal erosion.

(b) Stakeholders taking part in the management of floods.

Figure 6.4: Network of stakeholders, limiting their connections to plans dealing with a certain coastal risk (Erosion and inundation).

The involvement of a high amount of stakeholders within the planning of erosion leads to think that erosion is arising as a significant coastal risk at all levels. Erosion is introduced in the planning of the emergency, with the participation of PROTCIVIL, but also in prevention, especially with the cooperation of DGOTU and the introduction of this coastal risk within spatial and urban planning. Besides, the climate change factor is also considered when working with erosion, with the participation of OECC. Nevertheless, the connections among them are rather weak, partly because of the fact that four of the stakeholders here -ACA, AUTP, CHE and Subdirecció General de Ports i Aeroports (DGPORTS)-, when it comes to erosion planning, only take part in one plan each. Finally, it is also important to mention the presence of DGC in almost every plan related to erosion, which is revealed by the fact that it is connected to most of the corresponding stakeholders. This leads to think in a centralization of erosion governance in this state-level institution, DGC. In fact, DGC concentrates competences and decision-making capacity, while the rest of stakeholders remains subject to it with few or none decision-making power.

When it comes to **storm-induced inundations**, the structure of the network is rather different from erosion, though involving nearly the same set of stakeholders. Pictured in Figure 6.4b, the focus is set on the four-element group formed by the city council, DGOTU, PROTCIVIL and ACA. A cross management of inundation is observed, with the central positions of civil protection, on planning the emergency, and DGOTU, on the preventive stage. Besides, in comparison with erosion (Figure 6.4a), the presence of more edges with a weight higher to 1 denotes that the management of this risk is not focused on one central stakeholder, but on multiple entities, balancing the presence of the risk within phases and administrative levels.

Sea storms and marine pollution are the next coastal risks to consider separately. On the one hand, management of **sea storms** in the Catalan littoral is restricted to only three stakeholders - city council, private entity and civil protection -, defining a complete network of 3 nodes and 3 edges. It is important to recall that the management of sea storms is only planned on the emergency phase (mainly through the emergency plan INUNCAT), when these three stakeholders work together to mitigate possible damaging consequences.

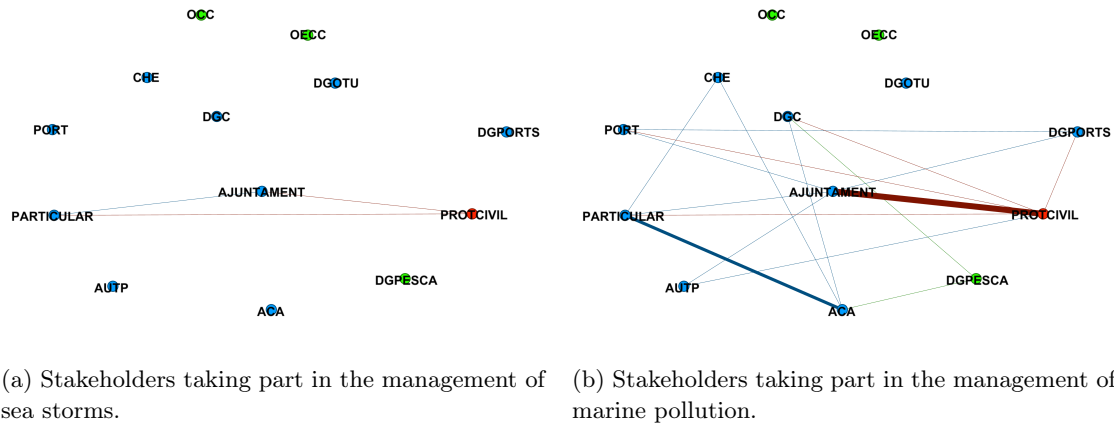


Figure 6.5: Network of stakeholders, limiting their connections to plans dealing with a certain coastal risk (Sea storms and marine pollution).

On the other hand, the corresponding network that comes out from limiting the network to those stakeholders taking part in **marine pollution** is quite more complex, as seen in Figure 6.5b. Ten stakeholders are involved within the management of marine pollution, which represent all of them excluding the climate change offices OECC and OCC (state and Catalan level) and the Catalan department of urban planning (DGOTU). There are 2 outstanding connections: PARTICULAR and ACA, working together in hydrological planning (PHE and PGDCFC); and the city council

and civil protection, especially in regard to harbour planning (PORTCAT and UPORTE) and also in emergency interventions (CAMCAT).

Finally, the new variable of **climate change** is introduced in the analysis (Figure 6.6a). It is the first risk that does not include the emergency perspective of civil protection, the city council or a private entity, which may lead to think on a broader view of this risk. Indeed, all plans dealing with climate change are from the prevention phase, so the corresponding nine stakeholders are connected through these plans, though some of them also take part in the planning of the emergency of other coastal risks. The Spanish office of climate change OECC together with DGC place themselves at the core of the network. It has to be mentioned that OECC is a step ahead of the Catalan office OCC, partly because the competences of the coast are at the state level.

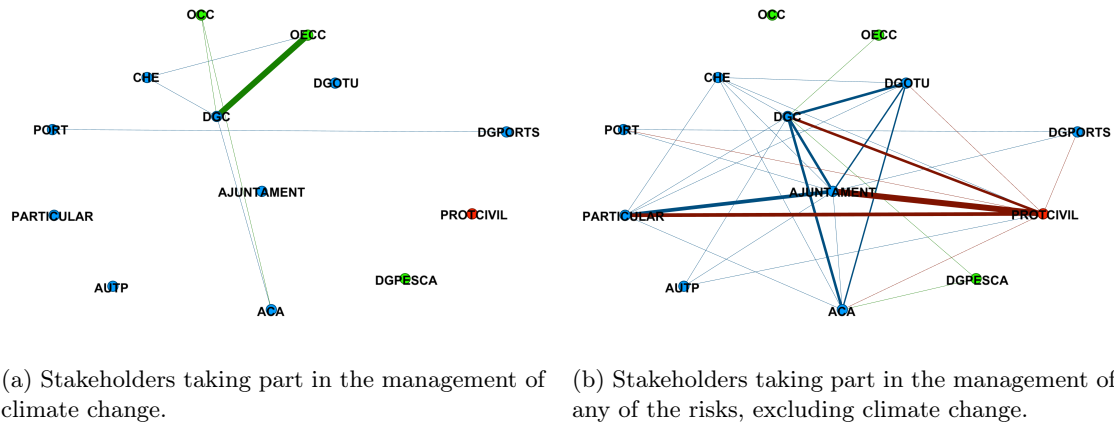


Figure 6.6: Network of stakeholders, limiting their connections to plans dealing with a certain coastal risk (Climate change).

In contrast, when considering all stakeholders except those that exclusively take part in the management of climate change, only the Catalan Office of climate change (OCC) stays isolated. This isolation exposes that the intervention competence of OCC is still weak, only taking action through SEA. Integration of climate change into coastal risk planning is therefore far from ideal: while governance of this broad risk is currently focused on the offices of climate change and DGC, coordination with stakeholders dealing with other risks seems to be rather insufficient. The inclusion of these stakeholders into planning not exclusive of climate change could be a first very necessary step to integrate the climate change perspective into future coastal risk management. With the new Climate Change Law (which is still a preliminary draft), it is expected that OCC will acquire a higher ability to influence on planning, and that climate change will become more significant and present within the aforementioned planning.

### 6.1.2 Risk planning analysis

A second approach to analyze coastal risk governance is through existing relations among plans according to the stakeholders they share. By projecting stakeholders on plans (following graph theory presented in Section 5.1), two plans are related if a certain stakeholder takes part in both. Thus, the one-mode projection used here is the complementary of the one in Section 6.1.1, where two stakeholders are connected if they take part in the same plan. The weight of a connection -edge in the network- between two nodes represents the number of common stakeholders: a stronger link in the network may reveal a closer relation in the reality. In addition, denser networks with higher edge weights may reveal more solid relationships and, consequently, more coordinated interventions when it comes to a risk.

Focusing on the first network (Figure 6.7a), the strongest relation links the drainage basin plans, PHE and PGDCFC, which are both central elements of the network. This network clearly shows what has already been mentioned about hydrological planning, being a proper example of holistic approach and integration of all different risks. Of special importance are the close connections among three emergency plans (PROCICAT, INUNCAT and CAMCAT) and among the hydrological plans, respectively. It is not strange that the three emergency plans are strongly connected: the activation of any of these plans not only involves the participation of civil protection, in charge of the activation itself of the emergency intervention, but also of the city council and the private entity affected by a risk. Thus, these 3 stakeholders define a robust relation among plans and, at the same time, corroborates the idea that planning of the emergency phase is currently more developed than the management of the prevention. Besides, sharing a high number of stakeholders may imply proper delimitation from one to another plan and avoid overlapping among them.

On the prevention phase, it is outstanding the nearly complete isolation of ESCACC, the Catalan strategy of adaptation to climate change. ESCACC is only connected to PGDCFC through the participation of OCC on both plans. The climate change factor is already being included in hydrological planning, though not quantitatively due to high uncertainties and low reliability of models at regional or local levels.

Narrowing to a local scope, the three corresponding plans – PAUT, PAM-PAEM and POUM – seem to be rather disconnected to the rest. Indeed, the city council or a private stakeholder (PARTICULAR) are their only connections to other plans. On Figure 6.7b, these three plans are excluded and the resulting network is clearer in terms of number of connections. The outcomes of the network analysis are very similar to the global picture with all the plans considered, as only edges to PAUT, PAM-PAEM or POUM have been dismissed.

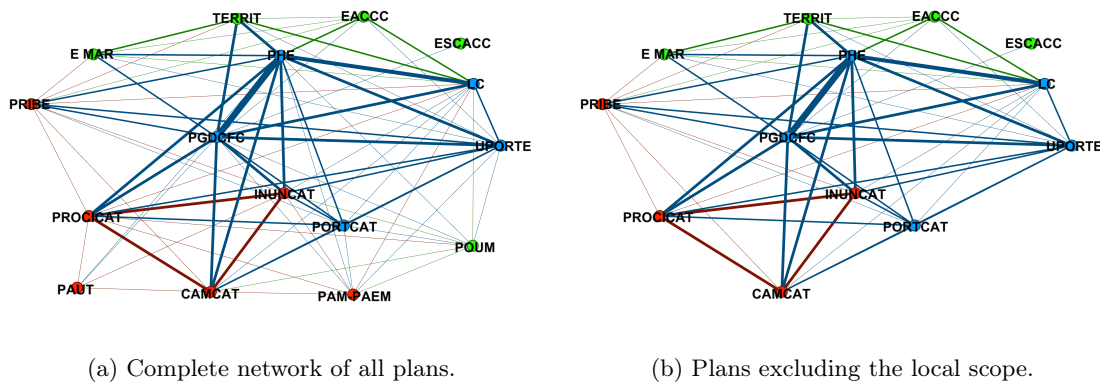


Figure 6.7: Network of plans, connected by common stakeholders.

Along the same lines as developed in Section 6.1.1, in this approach it is also suitable to carry out separated networks for each coastal risk. The objective is to determine which plans deal with the same risk and to analyze how connected they are.

Taking **erosion** as the first risk to study separately (Figure 6.8a), there are 7 plans that deal with it, mainly related to the hydrological planning and harbours. They are mostly associated to the prevention of the risk (indeed, none of them is a plan exclusively from the emergency phase) and they are interconnected to each other, with a density of 0,86, very high in the scale [0,1]. Placing this network in the context of the Catalan coast where erosion is very frequent and therefore it is a current concerning risk, one can get to the conclusion that, as its effects are seen on the short-term, it is already integrated into urban planning of the territory and its management is more coordinated. This is related to what resulted from Figure 6.4a where erosion arose as a coastal risk that is getting integrated within urban planning. However, it is also remarkable that the local



scope, directly affected by the physical deterioration and the consequent economic impact, does not participate in this management: PAM-PAEM, POUM and PAUT do not encompass erosion within their legislation.

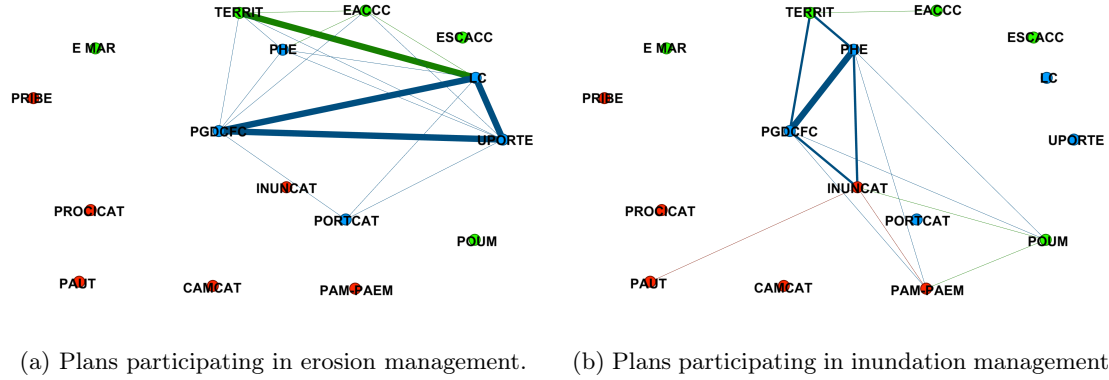


Figure 6.8: Network of plans, connected by stakeholders (Erosion and inundation).

In spite of what is stated above with the configuration of this network as a dense graph, it cannot be said that the governance of erosion is decentralized. Recalling Figure 6.4a, it has been observed that DGC is related to most of other stakeholders dealing with erosion. This leads to think that most of the connections among plans depicted here in Figure 6.8a are the result of the presence of DGC, therefore not revealing a decentralization of erosion management. In fact, it is known that LC is the leading tool that govern the rest of plans and stays at the top of the erosion governance hierarchy.

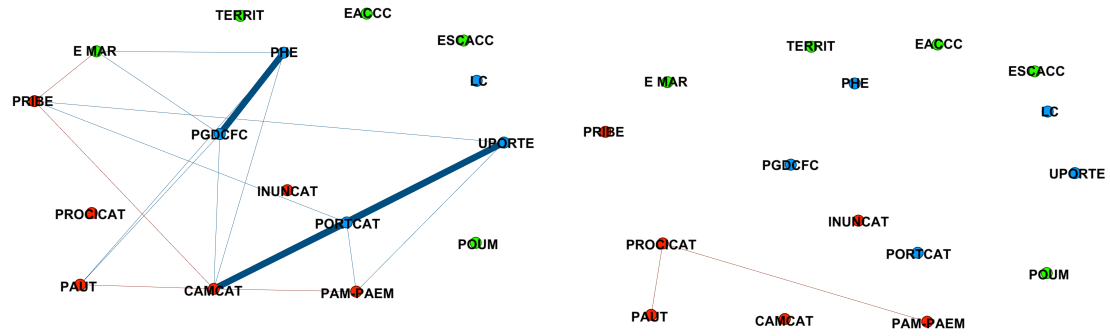
When focusing on **inundation** (Figure 6.8b), the result is considerably different. Firstly, and in line with results coming out from the complementary network (Figure 6.4b), one can observe a cross management of this risk as both emergency and prevention planning are present. On the one hand, immediate reaction by institutions may be needed to mitigate possible damage; on the other hand, inundation is starting to be considered within urban planning (for example, by prohibiting certain constructions in areas vulnerable to flooding). Another aspect to consider is that the local scope is included here on both phases of planning: with POUM for the planning of the prevention, and PAM-PAEM and PAUT for the planning of the emergency.

In regard to the structure of the network, a central set of four plans performs as the main link among all plans participating in flooding management. This core group is mainly formed by PGDCFC and PHE, from the hydrological planning, INUNCAT and TERRIT. The peripheral elements, basically the 3 local plans and EA0CC, are weakly connected to the core, with single edges in every relation. However, in contrast with the erosion network, stakeholders taking part in this planning are more diverse, include different geographical levels (state, Catalan and local scopes) and planning phases (prevention and emergency) and connections are not a result of one unique entity (as it is the case of DGC with erosion). This reveals that coordination among these plans is more decentralized.

When it comes to **marine pollution**, depicted in Figure 6.9a, a first characteristic to notice is the high number of plans involved with this risk (9), that leads to think on a broader vision of the risk. However, the graph density is 0,5 and, from all edges, there are only 3 noticeable connections which, in their turn, define two strong subsets of plans. In general, most of the links among plans dealing with water pollution are the result of sharing stakeholders such as the city council or a private entity. Consequently, it is not necessarily true that a larger number of plans dealing with a certain risk implies a more robust and coordinated management.



Conversely, the network of plans participating with **sea storm** events is extremely simple, as it only involves 3 plans (PROCICAT, PAUT and PAM-PAEM) and 2 edges (PAUT-PROCICAT and PROCICAT-PAM). Clearly, this simple structure represented in Figure 6.9b coincides with the one describing relations among stakeholders dealing with sea storms according to shared plans. All three plans take part in the emergency planning, as represented in Figure 6.9b. Indeed, on the local scope, PROCICAT is the root plan from where PAUT and PAM-PAEM derive, depending on whether it is a private entity or the city council that is responsible for the emergency area affected.



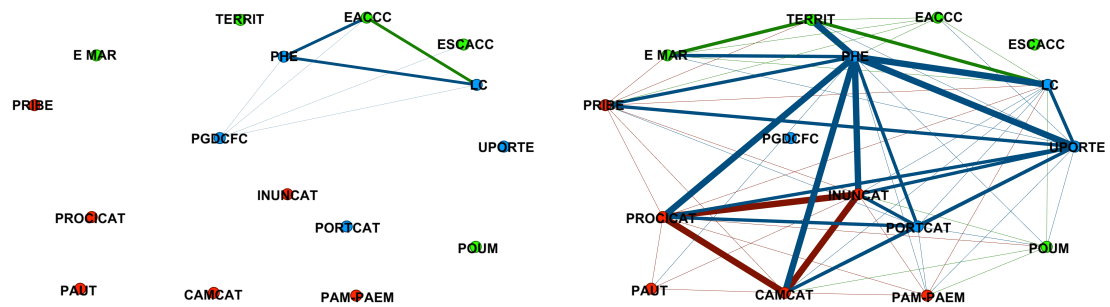
(a) Plans participating in marine pollution management.

(b) Plans participating in sea storms management.

Figure 6.9: Network of plans, connected by stakeholders (Marine pollution and sea storms).

As a last risk to consider separately, there is **climate change** which, indeed, is a phenomenon that will have a negative impact on all natural hazards mentioned above. Besides, climate change is an event that does not have immediate effects, such as flooding may have, and had not been declared as a significant hazard since recently. Accordingly, in Figure 6.10a it can be seen that the resulting network limited to current planning of climate change only involves 5 plans.

It is important to highlight the well-connected triad formed by LC, PHE and EACCC<sup>1</sup>, having in common both DGC and OECC as main stakeholders taking part in them. The General Direction of Coasts is also the link to PGDCFC. On the Catalan scope, ESCACC seems to be rather disconnected, as the only stakeholder driving this strategy is OCC, also taking part in PGDCFC.



(a) Plans participating in climate change management.

(b) All plans excluding the planning of climate change.

Figure 6.10: Network of plans, connected according to stakeholders: focus on climate change.

In contrast, excluding the climate change variable from the complete risk planning network, the

<sup>1</sup>Remember that EACCC is the strategy deriving from PNACC.

graph remains basically invariant. Notwithstanding that the structure is essentially the same, two of the plans just mentioned for climate change get isolated under these conditions: ESCACC and PGDCFC.

Merging the outcomes of networks in Figure 6.10 and the description of coastal risk planning in Catalonia in Section 4.1, it can be said that climate change is not present in risk planning in a stable and operational way. Indeed, the consideration of different scenarios of climate change into risk planning is currently exclusively left in hands of SEA. Again, it is expected that with the new Climate Change law, new management tools will arise in order to integrate more explicitly climate change into planning.

Everything aforementioned reinforces the complexity of the legal-administrative framework of coastal risk management. In general, Catalonia does not have a global rule that regulates natural risks in a holistic way and at the same time includes all aspects and elements related to natural hazards. Civil protection is the field that presents the most intensive and precise regulation with regard to public safety and interventions in front of emergency situations. Besides, the phase of emergency is exhaustive and detailed, and it is quite developed through civil protection plans (PROCICAT, CAMCAT, INUNCAT, or municipal or autoprotection plans). Whereas, planning of the preventive phase, as a way of incorporating the factor of natural risks into spatial planning, is not as developed in the current legislation.

In regard to structure, coastal risk governance still seem to be rather fragmented according to risks (flooding, erosion, storms, marine pollution). In the case of erosion, management is very centralized to one stakeholder (DGC). Opposite to it, flooding seems to be more decentralized since it includes hydrological planning concerned about the participation and coordination of its stakeholders; as well as marine protection, whose planning stays between centralization and decentralization.

The concentrated management of erosion is not in line with the perspective of Ernstson, Sörlin & Elmqvist (2008) that express that more segmented networks get to better outcomes when it comes to solving complex tasks, as subgroups can generate independent knowledge useful for different parts and scales of the problem. According to them, "segmented-decentralized structures reject any leaders to coordinate action on broader overarching concerns" (Ernstson, Sörlin & Elmqvist 2008). The objective should therefore be to segment coastal risk governance and to consider the importance of all levels in this management.

Finally, the inclusion of climate change as a variable to take into account in coastal management is still not as developed as it would be desirable. A first step would be to reinforce the role of stakeholders dealing with this natural hazard.

## 6.2 Statistical analysis on coastal risk perception

In this section, an analysis of the survey on social risk perception is carried out, both globally (all respondents together), and from a disaggregated perspective (responses from Alt Empordà and Maresme studied separately). The same four-part structure of the survey presented in Section 5.2 is used to analyze the results, starting with a characterization of respondents.

### 6.2.1 Respondent profile

The survey was answered by 52 local stakeholders. The answers date from the period comprised between February 11th and June 6th, 2014.

The final respondents were not equally distributed between the two study areas: 20 from Alt Empordà (38,5%) and 32 from Maresme (61,5%). It is important to disaggregate the results into the two areas to study how the social perception of natural hazards affecting the coast varies from one region to the other due to the corresponding contexts.

An important majority of the respondents were men, representing a 69% of the total sample of local stakeholders in front of the 31% of women. On the age partition, more than a 50% were encompassed on the range from 45 to 65 years-old.

Finally, on the distribution of respondents according to the sector they stand for, the local administration was the area most represented (38%), followed by the touristic sector (17%). The complete distribution per sector is depicted in Figure 6.11.

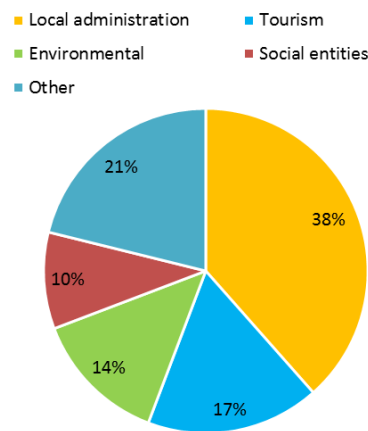


Figure 6.11: Distribution of respondents according to sector of representation.

### 6.2.2 Coastal problems and activities on the local scope

#### Main coastal concerns

A first interesting question to study is related to the environmental problems perceived on the local scale. Three out of eleven problems had to be highlighted by the respondent as the most significant ones, from the most to the least important. From a global perspective, the concern that repeats the most among respondents is *Beach erosion* (16,78%), followed by *Sea storms effects* and *Urban growth*, with a percentage of appearance of 14,09% each. However, this approach does not take into consideration the priorities each respondent gives to each problem.

In order to obtain the general perception of the main difficulties of the coast, formula 6.1 has been used to aggregate the different percentages of appearance of each environmental problem ( $i \in \{1, \dots, 11\}$ ) into a final percentage of coastal concern  $C_i$ . With that, the percentage of appearance as priority 1 is weighted by 3 in order to remark its importance, beyond the appearances as priorities 2 or 3.

$$C_i = \frac{3 \cdot p_{i1} + 2 \cdot p_{i2} + p_{i3}}{6}, \quad (6.1)$$

where  $p_{ij}$  ( $j \in \{1, \dots, 3\}$ ) is the percentage that environmental problem  $i$  appears as priority  $j$ .

Using this formula, the global results vary slightly. Here, not only considering the number of appearances of each problem, but also its significance according to the respondents, the two main concerns are *Beach erosion* (18,91%) and *Deterioration of the landscape* (16,35%). This indicates that not only do these two options appear multiple times in people's responses, but also that they mainly appear as a first or second priority.

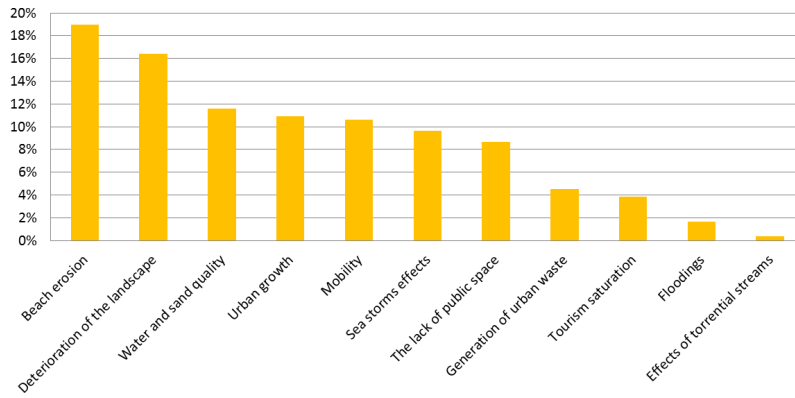


Figure 6.12: Main environmental problems: global results.

These results are somehow biased by the fact that there are more respondents from Maresme, thus it is convenient to separate results. Disaggregated results according to study area (Alt Empordà or Maresme) enable deeper analysis and comparison between these areas (Figure 6.13). Two different profiles are distinguished here: on the one hand, respondents from Maresme seem to give priority to environmental and natural hazards, such as Beach erosion, Deterioration of the landscape, Sea storm effects or Water and sand quality. On the other hand, respondents of Alt Empordà appear to be more concerned by problems with a more urban or touristic factor. Thus, the main highlighted problems here are Deterioration of the landscape, Mobility, Urban growth and Lack of public space.

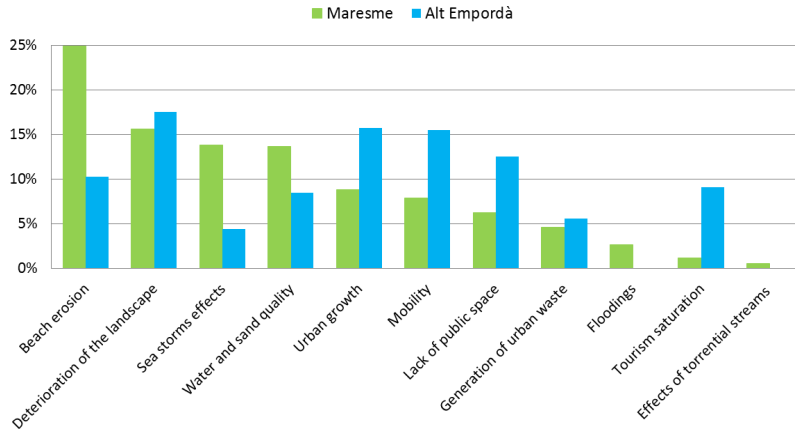


Figure 6.13: Main environmental problems: disaggregated results per study area.

The duality detected above is visibly in line with the contexts of each area (Section 4.3). Unstable dynamics of the coastal area in Maresme such as sediment deficit (causing continuous loss of sand) lead to a major concern on beach erosion and deterioration of the landscape. Respondents are clearly aware of the huge pressure the coast is undergoing and the consequences derived from this stress. In opposite, respondents of Alt Empordà highlight deterioration of landscape, urban growth and lack of public space as major environmental problems. This perception is most likely influenced by the high urbanization rate and the great pressure tourism is applying to the coastal areas.

Grouping these concerns into 4 thematic spheres, one can get a more generic outcome of the main perceived environmental problems the coast is undergoing. This classification is showed in Table 6.2.

Thematic scope	Problem
Natural risk	Beach erosion
	Sea storms effects
	Flooding
	Effects of torrential streams
Environmental quality	Water and sand quality
	Deterioration of the landscape
	Generation of urban waste
Urban planning	Urban growth
	Mobility
	Lack of public space
Tourism	Tourism saturation

Table 6.2: Environmental problems group by thematic scope.

The classification enables a more general comparison of risk perception between the two areas of study. As mentioned above, and as seen in Figure 6.14, Maresme seems to perceive more significantly natural risks on the coastal area, whereas Alt Empordà takes a closer look on urban concerns. Again, this is clearly along the same lines as the contexts of Maresme and Alt Empordà. On the former case, erosion of the seafront and the consequent effects are the focus of concern, while on the latter case, the impacts of the sun and beach tourism and the urban sprawl related are the center of attention (Section 4.3).

### Main activities of the areas

Respondents had to arrange four activities, according to their preferences: enjoy nature and landscape, do sport, walk, and swim and sunbathe. The most common activity in terms of number of appearance is clearly *Swim and sunbathe*, placed as the first option by an important 79% of respondents. In order to take into account all four priorities and get the final aggregated percentage of use for each activity ( $U_i$ ,  $i \in \{1, \dots, 4\}$ ), equation 6.2 is used. It gives more significance to an activity if it appears as the first option, and successively with second, third and fourth options.

$$U_i = \frac{4 \cdot p_{i1} + 3 \cdot p_{i2} + 2 \cdot p_{i3} + p_{i4}}{10}, \quad (6.2)$$

where  $p_{ij}$  ( $j \in \{1, \dots, 4\}$ ) is the percentage that activity  $i$  appears as priority  $j$ .

According to this aggregation, and from a global perspective, swimming and sunbathing are the most common activity (36,7%), followed by walking (21,9%), doing sport (20,8%) and enjoying

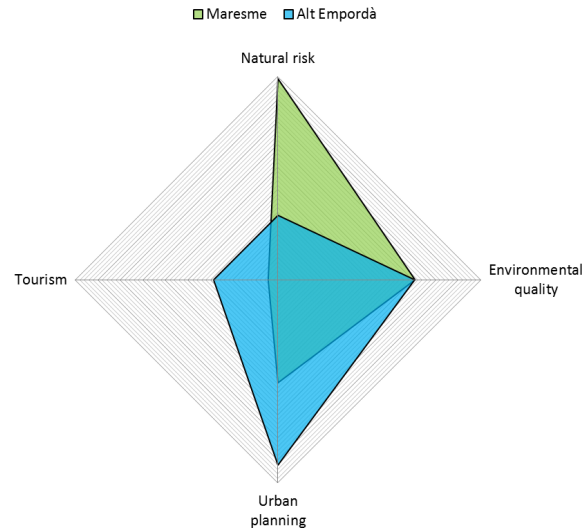


Figure 6.14: Thematic spheres: disaggregated results per area.

nature and landscape (20,6%), which present similar results. The results are quite similar when separating the answers according to area (see Figure 6.15), with swimming and sunbathing as the main activity the respondents develop in their coastal area. Both areas have an important touristic impact, especially during summer with the use of their beaches. This is clearly reflected in the survey when swimming and sunbathing arises as the main activity developed in both coasts. This type of result is typical in the Mediterranean context, where the recreational role of the coast linked to the "sun and beach" is widespread.

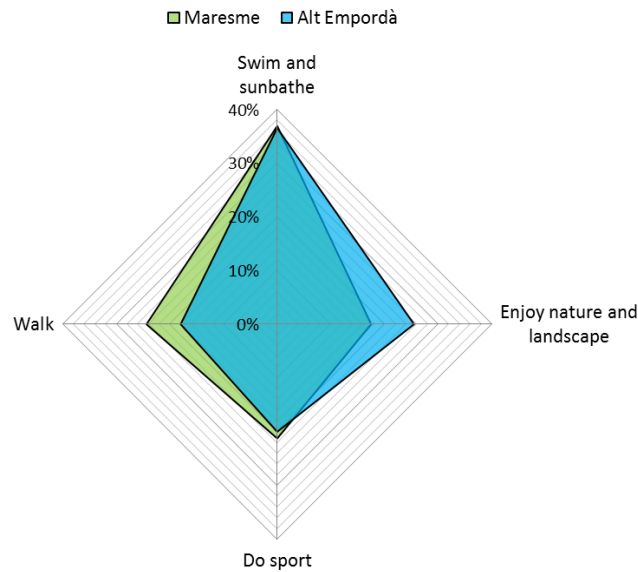


Figure 6.15: Most important coastal activities according to area of study.

### 6.2.3 Perception of coastal risks and their management

#### Causal factors of natural hazards

The importance of several factors that may cause certain risks on the coastal area is considered in this part. Respondents were asked to evaluate in a Likert scale 1-5, the importance of each factor

(ranging from 1 as little important, to 5 as very important). Disaggregated results per study area are considered directly to avoid biased results coming from the majority of Maresme respondents.

**Erosion** is taken as the first risk to study. The primary aspect to point out (Figure 6.16) is the tougher perception of respondents from Maresme: in average, the importance of every factor causing erosion is higher for respondents from Maresme than from Alt Empordà. In Maresme, the lack of beach nourishment (significance of 4,3) and marine engineering works (3,9) stand out. In contrast, the most important factors by respondents from Alt Empordà are the frequency and intensity of sea storms (3,3) and marine engineering works (3,2).

These results of social perception are clearly in line with the contexts in each area, especially in Maresme where the main pressure to the coastal system is regression of beaches and erosion and, consequently, the level of concern is high. Besides, the lack of beach nourishment is the factor causing erosion that varies most significantly from one area to the other, becoming the differentiating object between both coastal areas.

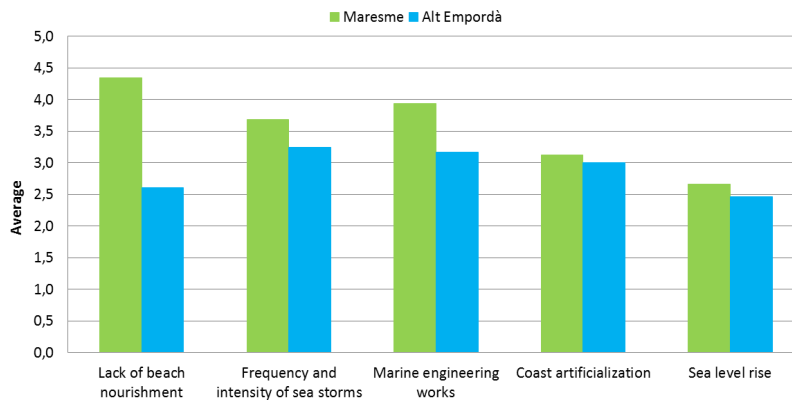


Figure 6.16: Most important factors causing erosion.

These results were obtained without taking into account 9 No Answer (N/A) out of the 260 possibilities (5 factors for each of the 52 respondents), which represent a 3,5% of null replies.

**Marine and sand pollution**, as seen above in coastal concerns, is not one of the most important environmental problems highlighted in the study areas. Accordingly, the importance scores given by respondents are considerably lower than with beach erosion (Figure 6.17).

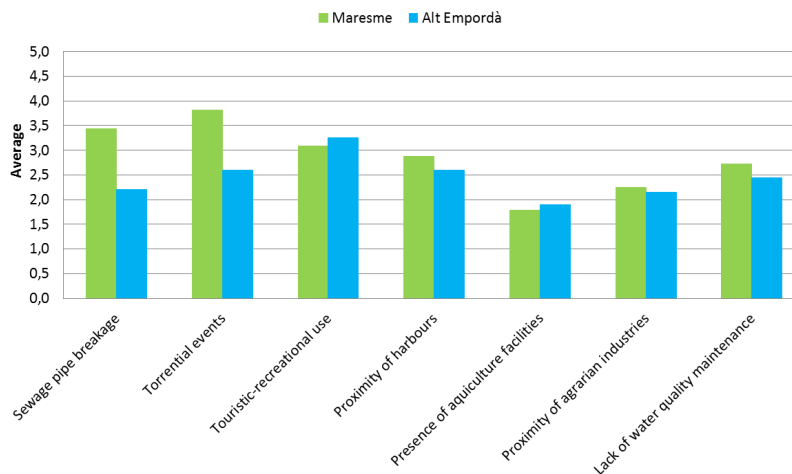


Figure 6.17: Most important factors causing marine and sand pollution.

The most significant factor of pollution according to Maresme respondents are torrential events (importance of 3,8), the breakage of sewage pipes (3,4) and touristic-recreational uses (3,1). In the case of Alt Empordà, the touristic-recreational use is seen as the main cause of pollution (3,3), followed by torrential events (2,6) and the proximity of harbours (2,6). Again, social perception in Maresme is generally tougher than in Alt Empordà, with the exception of touristic-recreational use. This last factor is in line with the significance of tourism and its consequences to the environment in Alt Empordà and therefore seen as the main cause of sand and marine pollution. The rate in Maresme is lower (rated 3), though still significant as a factor of sand and marine pollution.

In both areas, the factor considered the least important is the presence of aquiculture facilities.

In regard to **flooding**, factors of both continental and marine origin have been considered. With the exception of sea level rise, Maresme respondents evaluate as more important than Alt Empordà respondents all factors that cause inundations. This observation is also coherent with risk perception aforementioned, when respondents from Maresme displayed a higher perception of natural hazards.

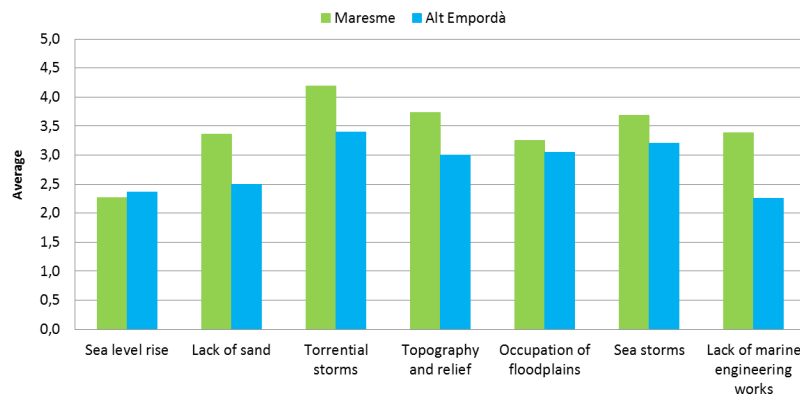


Figure 6.18: Most important factors causing inundations.

As shown in Figure 6.18, torrential storms stand out as the factor perceived by respondents as the most important that affects flooding in average. When it comes to determining the variable least influencing on flooding, respondents from Alt Empordà opt for the lack of marine engineering works, whereas respondents from Maresme perceive sea level rise as a minor factor. Different from the overall tone, it is noticeable the large difference in the average valuation of lack of engineering works (more than 1,1 points higher among Maresme respondents) and lack of sand (0,9 points higher among Maresme respondents).

It seems quite clear that in this section about causal factors of natural hazards, all results are geographic context dependent. The cohabitation for decades with natural phenomena and hazards carries the population to acquire knowledge about the origin of these problems approximate to the scientific reality.

### Evolution of coastal natural hazards

To study the changes the coast is experiencing in both areas, respondents' opinions are considered regarding their perception on the width of the beaches and the frequency of river floods and sea storms. In the former viewpoint, respondents were asked whether they were perceiving an enlargement or a regression of the beaches and, if that was the case, what was the scale of this variation (more than 10 meters, less than 10 meters, etc.). In the latter case, respondents had to express if they had noticed an increase or decrease in the number and intensity of river floods and sea storms.



First aspect to notice is the high percentage of no answers (N/A): a 21% in the case of the beach width (equivalent to 11 respondents), a 15% with river floods and a 17% for sea storms. Besides, the percentage of this type of answer is considerably higher among respondents from Alt Empordà than Maresme. As an example, an important 40% of respondents from Alt Empordà do not know or are not willing to answer how the width of beaches has changed. This has a real impact on the final results about perception.

In general, the perception of respondents is of a clear erosion of beaches, a decrease in the number of river floods and a decrease in sea storms. However, this general perception varies significantly from one area to the other, considering only replied answers (different from N/A). This variation from one study area to the other is visibly influenced by their particular context.

Firstly, with regard to the perception in the beach width, the regression of this coastal area is globally perceived. However, while a 50% of answers in Alt Empordà accept a backward movement of the beach, this percentage rises up to 72% in Maresme, as depicted in Figure 6.19. Here, it is important to recall that, as observed in Figure 6.13, beach erosion is already the main environmental problem identified by Maresme respondents, thus it should not be surprising that a great majority of them perceive a regression of beach areas.

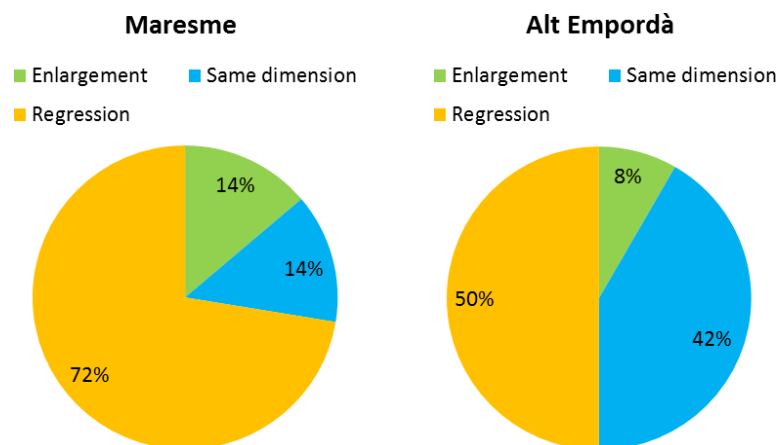


Figure 6.19: Perception of the variation on beach width.

When considering river floods (Figure 6.20), the decrease in the frequency of these events is more visible within Alt Empordà respondents. Indeed, out the 16 people from Alt Empordà that answered this question, 12 have perceived a reduction on the number and intensity of floods, and none of them an increase.

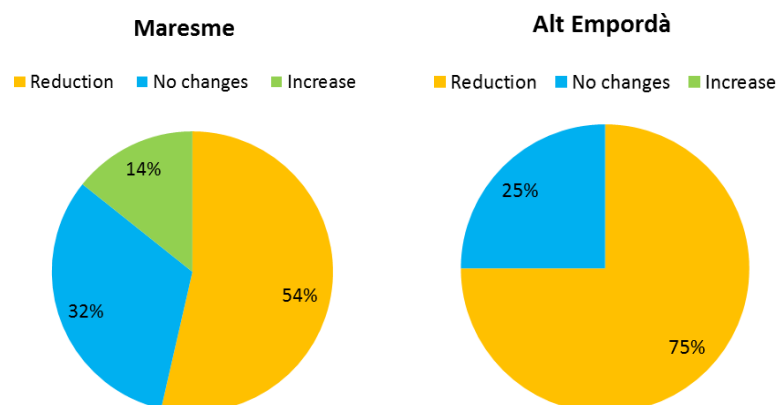


Figure 6.20: Perception of variation on the frequency and intensity of river floods.

Finally, in regard to sea storms (Figure 6.21), the general perception is not as direct. In Maresme, increase, decrease and no change answers are equally distributed. Whereas, in Alt Empordà, there is a majority response (54%) towards a reduction in the number of sea storms.

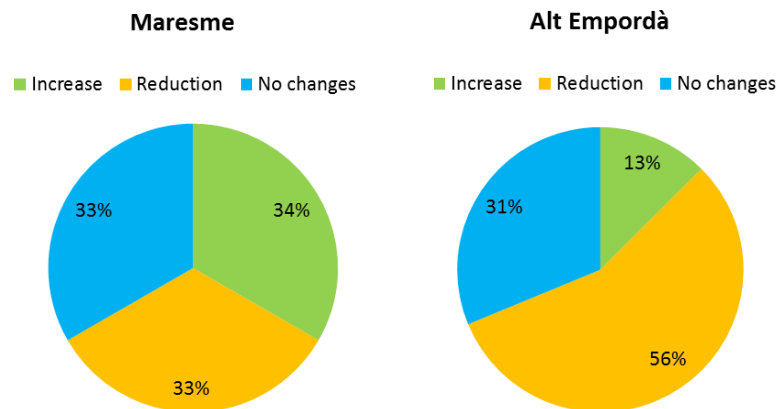


Figure 6.21: Perception of variation on the frequency and intensity of sea storms.

### Socio-economic and environmental impacts of natural hazards

On a Likert scale 1-5, respondents valued the socio-economic and environmental impact of mentioned natural phenomena on different elements in Maresme and Alt Empordà, where 1 was the lowest impact, and 5 the highest. Both physical elements (such as surface of beaches) and non-physical (such as the touristic sector) were included within the list to evaluate.

The major impact detected is the surface of beaches, with an average valuation of 3,6. Comfort on the beach (3,5) is close up following. Disaggregated results per area change, especially in Alt Empordà as Maresme respondents are the majority and have a major influence on the overall results. Perceived impact in Maresme is mainly harder than in Alt Empordà. Of special attention is the impact of natural events on the surface of the beach: limiting results only to Maresme respondents, the impact is valued higher, with a rate of 3,97. These impacts on the beaches are again in line with the context of Maresme, having beach erosion as its main concern. On the other hand, according to respondents from Alt Empordà, beach surface, with a slightly lower valuation (3,1), is not the most affected element. The most significant impact according to these respondents is on the comfort of the beach (3,3), followed by fishing activities (3,1), the landscape (3,1) and, also, beach surface (3,1). All these four affected elements are mostly related to the massive presence of tourism in the coastal area of Alt Empordà.

It is also important to highlight that fishing activities and harbours are the elements that have been rated by fewer respondents, with 7 N/A (13,5%) and 6 N/A (11,5%), respectively. This leads to think that impacts on these elements are less perceived by social stakeholders, or that it is more difficult to valuate.

### Degree of confidence

Respondents are asked to express their level of confidence towards institutions and organizations offering solutions to coastal risks, as well as towards different management tools existent on the current legislation (state, regional or local levels). In this case, answers are not much geographic-context dependent but more influenced by the ideology of each respondent.

Starting with **institutions and organizations**, a 4-level rating scale is applied for each of them: "Not confident at all", "Slightly confident", "Moderately confident" and "Extremely confident".

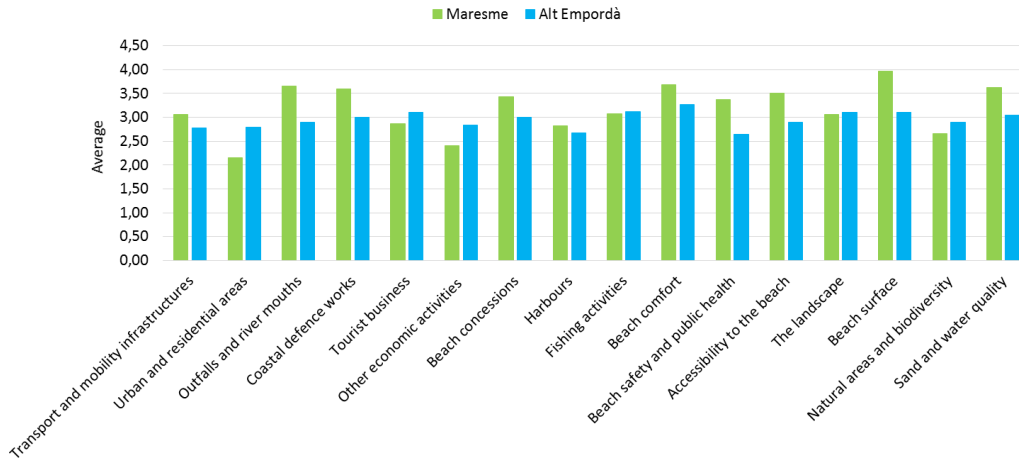


Figure 6.22: Average perceived impact on different elements.

In order to aggregate these different options into a final confidence result  $DC_i$ , Equation 6.3 is used for each institution or organization  $i$  considered ( $i \in \{1, \dots, 15\}$ ).

$$DC_i = 3 \cdot c_{i1} + 2 \cdot c_{i2} + c_{i3} - c_{i4}, \quad (6.3)$$

where  $c_{i1}$  indicates the number of "Extremely confident" responses for institution  $i$ ;  $c_{i2}$ , of "Moderately confident";  $c_{i3}$ , of "Slightly confident"; and  $c_{i4}$ , of "Not confident at all". The final result  $DC_i$  may fluctuate in the set  $\{-52, \dots, 156\}$ , being the lower bound (-52), the most pessimistic situation when an institution is considered not confident at all by all respondents; and the upper bound (156), the most optimistic condition, with all respondents being completely confident.

Complete results are seen in Figure 6.23, where a first aspect to stand out is that, in general, the confidence towards institutions is considerably higher among respondents from Maresme than from Alt Empordà. In both areas, scientists and universities are considered the most trustworthy ones, among all institutions listed in the survey. In the corresponding second places, coastal services are also highly rated in both areas.

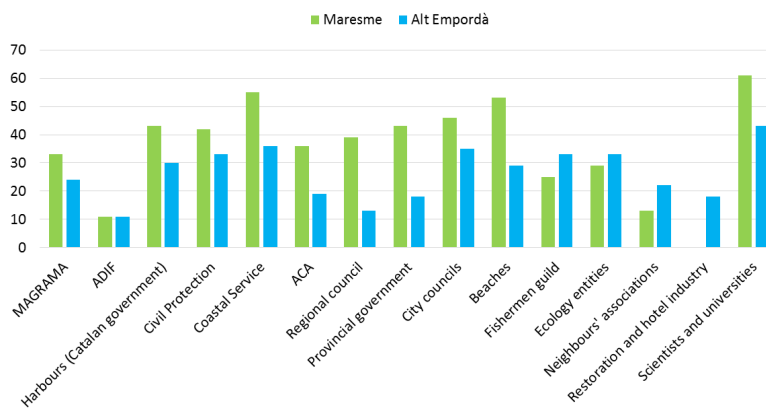


Figure 6.23: Average degree of confidence towards different institutions.

It is interesting to notice that the institution that is most valued (university and scientists) stays at the edge of politics or any kind of governmental actions, in a way to remain independent as an entity. Also noticeable is the good standing of the city council on the overall ranking of both areas, as an institution on the local scope. This confidence towards the city council stays in line with the

central position of this local institution in coastal risk governance, as it has been seen through the network analysis. The key role of the city council when it comes to emergencies in the coast is most probably the determining factor of the confidence towards it. In contrast, entities at the state level are less valued by respondents, especially Administrador de Infraestructuras Ferroviarias (ADIF)<sup>2</sup> which places last and second to last according to respondents from Alt Empordà and Maresme, respectively.

With regard to confidence on **management tools**, the Likert scale and the aggregation formula aforementioned are also used to get a final rate for each of the seven tools presented ( $i \in \{1, \dots, 7\}$ ). On average, emergency plans, such as INUNCAT, PROCICAT and CAMCAT, stand out as the most trustworthy instruments, in both the general and the disaggregated results. This can be seen on Figure 6.24. On the other side, planning instruments on the prevention phase, such as spatial planning or POUM, are especially disadvantaged. Again, the outcomes from this chart can be related to the results of network analysis on coastal risk statutory planning (Section 6.1), where planning of the emergency was clearly more coordinated and developed than prevention.

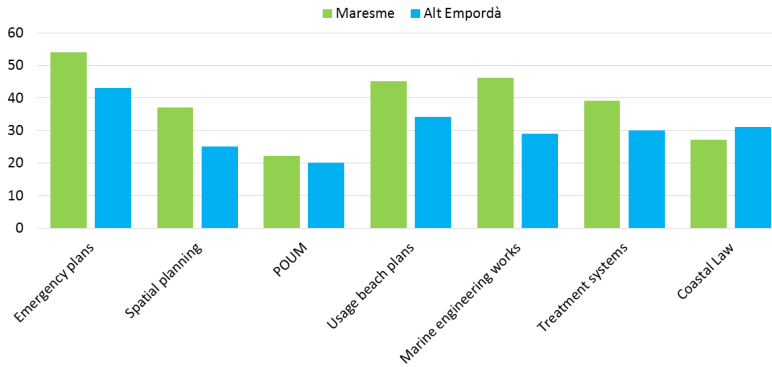


Figure 6.24: Average degree of confidence towards different coastal management tools.

Of special interest are the marine engineering works, rated very differently from one area to the other. In the Maresme context, this hard measure is positioned above the average confidence rate, being the second tool in terms of confidence. In Alt Empordà, these interventions are not that well considered and stay below the average value. These results link to the perception that a lack of marine engineering works is one of the factors most affecting inundations, by respondents from Maresme; while according to Alt Empordà respondents, this lack is not such an important factor. This is seen above in Figure 6.18.

### Management strategies

Five different management strategies had to be ordered by respondents according to their priorities, where 1 is the most urgent strategy to apply and 5 is the least critical one. An analogous formula of Equation 6.1 is used here to aggregate the different positions  $p_j$  ( $j \in \{1, \dots, 5\}$ ) of each strategy  $i$  ( $i \in \{1, \dots, 5\}$ ) into one final result  $MS_i$ . Let  $p_{ij}$  be the percentage of appearance of strategy  $i$  as priority number  $j$ .

$$MS_i = \frac{5 \cdot p_{i1} + 4 \cdot p_{i2} + 3 \cdot p_{i3} + 2 \cdot p_{i4} + p_{i5}}{15} \quad (6.4)$$

Priorities among respondents from Maresme and Alt Empordà are quite similar. Represented in Figure 6.25, planning and coordination is declared the most imperative strategy, followed by the conservation of natural values in the coast.

<sup>2</sup>ADIF is a Spanish state-owned company charged with the management of most of Spain's railway infrastructure.

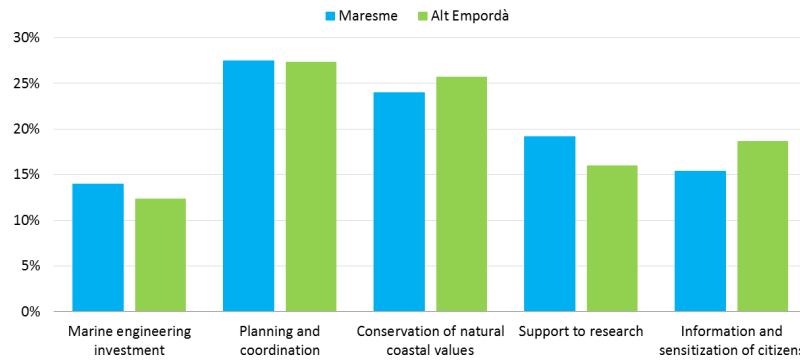


Figure 6.25: Average priority percentage of different management strategies.

Investment on marine engineering places last in the priority ranking. A distinguishable aspect between the two areas is that, according to its respondents, Maresme is slightly more willing to these hard interventions. This predisposition follows the same lines as the level of confidence, where these same respondents from Maresme positioned marine engineering works as the second tool in terms of confidence.

Another aspect quite surprising is that, though scientists and university are the most trustworthy entity (as seen in Figure 6.23), supporting and pushing research is not seen as a major priority in none of the two study areas.

Classifying these priorities according to the 4 main sectors -tourism, local administration, environmental and social entities-, Figure 6.26 is obtained. These four sectors include 41 out of the 52 respondents (79%). Though many responses are quite similar among sectors, there are two aspects to emphasize. Firstly, it can be observed that marine engineering investment is clearly more accepted within the touristic and public administration sectors, maybe seen as an immediate response to beach erosion. Contrary to this, when it comes to supporting research, environmental and social entities seem to be more disposed to, though still placing it as the third priority.

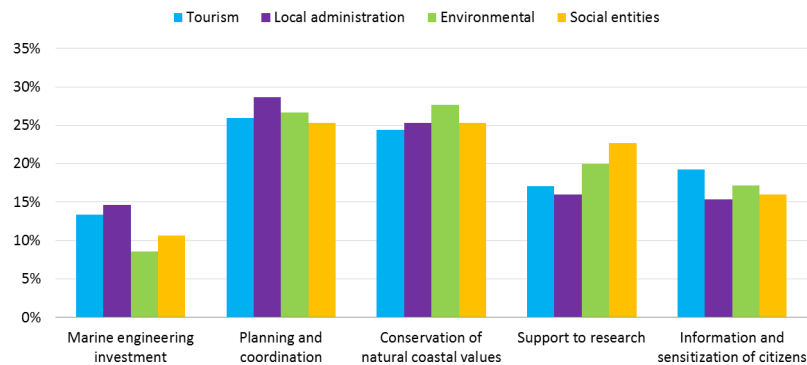


Figure 6.26: Average priority percentage of different management strategies according to economic sector.

In a few words, outcomes (in average) from the survey reveal the presence of two profiles of respondents, mainly coinciding with the two study areas. The different contexts of Maresme and Alt Empordà clearly have an influence on risk perception of their inhabitants, as well as on their opinions about how these hazards should be managed.

Both areas experience a great pressure in their coastal areas, mainly used for the same purposes, though these squeezes do not always have the same origin. Maresme suffers from inland pressure with a high urban density, accumulation of transport infrastructures, massive use of beaches, etc.

At the same time, the area is undergoing severe coastal regression and continuous necessity of sand nourishment to regenerate beaches, aggravated by numerous natural events such as sea storms. All this results in a high perception of coastal hazards and a good will of improving governance. For this improvement, it is necessary to enhance coordination among stakeholders taking part in coastal risk management and among plans, mainly integrating natural risks into the prevention phase. In turn, Alt Empordà is mostly suffering from massive tourism. Sun and beach tourism and the urban sprawl related, though being one of the main economic drivers of the area, not only conflicts with the normal development of local day-to-day life but it also damages the natural environment.

# Discussion

In this chapter, all aspects covered in the research are looked over in a brief discussion as a way to summarize the findings, establish connections among them, and achieve consistent outcomes for the main objectives of the thesis.

## 7.1 Risk planning analysis

Network analysis is used in this research with the aim of assessing the current situation of coastal risk management in Catalonia and contributing to the shift towards a more integrated planning. The use of one-mode projections over plans dealing with coastal risks, help corroborating the conclusions that had previously come out from qualitative analysis of risk planning in the Catalan coast. On one hand, in regard to the emergency phase, planning is strongly intertwined and well coordinated. Civil protection performs the key role of this planning, by activating the suitable plan to face a certain risk (mainly, INUNCAT, PROCICAT or CAMCAT) and mobilizing and coordinating all involved stakeholders (such as the city council or a private entity, that could be affected by some risk). This also results into a better consideration and a higher degree of confidence by local stakeholders, the ones experiencing first-hand consequences of natural hazards in the coast. In contrast, the situation of the prevention phase is quite different, as the pertinent planning is still unfocused and it is lacking a global integration of coastal risks into spatial and urban planning of a territory.

Not only is planning of prevention in the Catalan coast behind when it comes to internal coordination, but there is also an obvious lack of connection with emergency planning. The integration of both phases would represent taking a step forward towards a broader holistic approach and, consequently, approaching one of the guidelines of ICZM to achieve a more unified management of coastal areas. As a process to enhance integrated management, decentralization of competencies and responsibilities is believed to be a significant option, through the presence of independent but coordinated governance groups, commonly denoted as *polycentric systems* (Pahl-Wostl 2009). These systems, that avoid focusing all risk management in one single stakeholder or group of stakeholders, have a higher ability to adapt to a changing environment. This ability is essential to face global environmental change, not only occurring fast but on multiple fronts: processes such as climate change or depletion of natural resources are interacting with each other in complex and surprising ways. In coastal areas, the gradual degradation as well as the loss of ecological resilience urgently demand this integration and coordination, as the climate change factor will gradually gain more importance, aggravating risk events and their consequences to coastal systems.

In effect, regarding climate change, some authors believe that a combination of both mitigation and adaptation strategies are essential in coastal areas to develop proper responses. A key aspect to successfully develop and implement these strategies is to change the competency scope. Traditionally, adaptation planning and policy was viewed as a competency of national governments

and was implemented through national mechanisms, such as national adaptation programs. However, the emphasis should be placed on the development of local level strategies, though requiring support and involvement of all cross-level stakeholders. The increasing emphasis on local level adaptation reflects the likelihood that climate change impacts will be experienced locally, as well as the fact that local governance entities are often the competent body for managing and ameliorating such impacts. As Flannery et al. (2015) state "risk mitigation and adaption strategies need to be built into spatial planning processes of local governments to reduce the vulnerability of coastal populations", though taking into account that local government entities operate within a complex hierarchical governance framework and that consequently they are constrained by higher level plans, policies and legislation.

In terms of mitigating the impact of coastal risks, Flannery et al. (2015) declare that local authorities often rely on engineering solutions, even though these human modifications of the coast, aiming at reducing "exposure" to risks, may in fact inadvertently exacerbate their impacts and increase vulnerability. Social perception assessed in the present research reflects that, on average, marine engineering investment is the last priority as a management strategy, though being this option more accepted among representatives of local administration and tourism, than among social and environmental entities. In contrast, and in line with the aim of shifting towards an integrated coastal zone management, planning and coordination is seen as the most suitable strategy.

As an introduction of what will continue in Section 7.2, some authors claim that it is critically important to understand how coastal risks are perceived by the public in order to design effective risk management strategies. At the same time, risk governance and social networks among stakeholders also influence risk perception. According to Morrow (2009), perception is "the core issue in risk decisions" and agrees that public perceptions are the result of intuitive biases, economic interests and cultural values (Morrow 2009). The inclusion of the general public into the design of risk management (even if it is only through their perceptions) is clearly in line with the principles for an integrated strategic coastal risk management. One of them specifically maintains the need for a participatory approach of coastal risk management, including wide levels of consultation and participation with stakeholders and the general public. The active involvement of a broad and diverse range of stakeholders is believed to be essential for an effective implementation of ICZM. In a few words, an overall planning system that guarantees integration among administrative levels and sectorial policies is required to increase overall coastal safety.

## 7.2 Risk perception analysis

Perception is the personal interpretation of one's environment that, being a subjective opinion depending on each individual, can be influenced by different external variables. In regard to risk perception, there are many factors that may impact, starting with the own knowledge of the risk, personal beliefs, cultural values or social standards. One of these factors is the geographical aspect that, in terms of location of the area considered, has a clear impact on perception, given that each geographic context has its concerns, climate conditions, demographic characteristics, economic sectors, etc. This is the case of Alt Empordà and Maresme, the two study areas of this research, selected for being two especially vulnerable regions in the Catalan littoral that are experiencing the consequences of multiple risks and that, consequently, require proper planning in regard to them.

Despite the fact that these areas are rather close to each other (around 150 km away), certain characteristics of general coastal risk perception can noticeably be distinguished among respondents from one and the other area. Bearing in mind results presented in Section 6.2, especially relevant are the observed differences on the perception of risk and the affectation that natural hazards have on beaches, more noticeable on average among respondents from Maresme; as well as on the



application of certain hard measures in the coastal system, when respondents of Maresme seem to be, on average, more willing to engineering works as part of the solution.

The dual profile of respondents is, as mentioned, in line with the geographical contexts. On the one hand, the major current pressure in Alt Empordà are the impacts of the sun and beach tourism and the urban sprawl related, which conflict with the preservation of the ecological richness, especially in the seafront. At the same time, tourism represents the main economic sector of Alt Empordà, worsening this conflict of interests. The approval of LC as well as the declaration of two ecologically rich areas, *Cap de Creus* and *Aiguamolls de l'Empordà*, as natural parks was key to slow down the rate of urbanization, though not enough to end up with the pressure of mass tourism. On the other hand, Maresme is a more permanent residence region receiving one-day visitors to the beaches, mainly from Barcelona and other close by areas. The physical configuration of the region together with the saturation of the waterfront line, not only with residential constructions but also with multiple transport infrastructures (basically, the railroad track and the motorway), makes Maresme especially endangered by natural hazards at the coast (such as storms or erosion).

For everything mentioned above, it is clear that, though sharing many aspects, the realities in the coast of Maresme and Alt Empordà are dissimilar. This implies that the needs of the coast and the inhabitants from one area and the other also vary, requiring a management and interventions adapted to these necessities.

## 7.3 Methodological innovation

The introduction of a methodological innovation was one of the main objectives of this research. As with every innovation, the methodological novelty, consisting in using network analysis as a support tool to qualitative analysis, presented both strengths and weaknesses. All these characteristics are discussed here, with the intention to suggest some changes or different approaches to improve further research works.

On the one hand, starting with detected weaknesses, the first and maybe most significant aspect to point out is that unipartite networks imply an important loss of information. Recall that, while bipartite networks (here obtained directly from the data base of plans, stakeholders and risks) represent all existing connections among element from different types, one-mode projections transform these graphs into networks of one unique type. Hence, the use of this method to networks enable assessing the degree of relationship and closeness between two element, but details on what exactly is connecting these two elements vanish. For instance, while one-mode projections may reveal that stakeholder 1 and stakeholder 2 share the management of 3 plans, one could not know which plans are. In order to get this information, it would be necessary to consult the initial data base or original network. As Newman (2010) expresses "[the construction of one-mode projections] discards a lot of the information present in the structure of the original bipartite network and hence it is, in a sense, a less powerful representation of our data".

At the same time, the initial data base was a rather simplified representation of reality, as the intention was to get a final object that enabled working with networks. In effect, the data spreadsheet was designed in order to get each plan connected to as many risks it somehow deals with and to as many stakeholders it involves, directly or indirectly. This data base has been modified throughout the entire research period to adjust it as much as possible to the reality. Nevertheless, there are many aspects that the design of the data base does not allow to specify and that, consequently, are dismissed from the final network analysis, such as hierarchies among plans or stakeholders.

On the other hand, the method applied here present strengths. Firstly, the use of simple weighting in one-mode projections (instead of non-weighted edges) is itself a positive point of the methodology, as it enables to capture some more information of the original bipartite graph. With that, it is meant that, different from regular one-mode projections, the intensity of the connection between

two nodes is depicted by weighting the corresponding edges, thus indicating stronger and weaker relationships.

The most obvious strength of this method is the potential and power it has as a visualization tool, turning one-mode projections, and networks in general, into a proper supporting instrument for qualitative analysis. Indeed, once one has already developed its research hypothesis, network analysis and one-mode projections can help representing and corroborating (or dismissing) these hypothesis. In some occasions, they could even show unperceived aspects of the qualitative analysis. The use of different colors and sizes for nodes, as well as filters by weight for edges are complementary features that enhance the outcomes of network analysis.

# Conclusions

The initial guidelines thought for this thesis were to develop a map of stakeholders involved in coastal risk management within the Catalan littoral, as well as to analyze relations among stakeholders and risk planning tools. The intention was to introduce a methodological innovation into traditional qualitative analysis. The new approach consisted in using network analysis to support qualitative analysis, as a procedure to get to new results or reinforce (or discard) preliminary ones.

Following these guidelines, networks on both stakeholders and plans have been developed in order to analyze the governance of coastal risks in Catalonia. This has resulted in the observation of a rather segmented and unbalanced planning of risk, as well as in an improvable coordination among stakeholders. In general, networks have strongly contributed to visualize the complexity of the legal and administrative framework of the Catalan coastal risk planning.

In regard to the study of social perception at the local level, statistical analysis has been applied and has enabled the identification of a geographic-context dependence on risk perception and on the prioritization of management strategies. The impact of the geographic variable suggests the necessity of adapting plans and management to each context or reality, and taking into consideration public perceptions and inhabitants' opinions when designing strategies. In contrast, it is believed that other types of perception such as confidence towards institutions and management tools have an ideological component, thus not depending on the geographic area but on values and ideals of each sector of the society. Studying this ideological dependence would imply a step forward in this research.

The inclusion of climate change into risk planning and, especially, into coastal risk management is still rather insufficient, with very few stakeholders and plans directly dealing with it. Consequences of climate change will get more and more obvious in the following decades, and coastal areas are expected to be especially affected, partly because of the high level urbanization they are experiencing. Further studies on climate change and natural hazards that will be aggravated by it, are essential to avoid, or mitigate to the largest extent, damaging effects to the environment and to human communities.

As a way of contributing to these studies about effects of climate change in coastal areas, outcomes from this work aim at improving understanding of coastal risk governance at the Catalan level and provide guidelines and suggestions for future research. These upcoming studies should definitely consider the inclusion of network analysis as a complementary tool to qualitative analysis. From the perspective of this work, the methodological innovation is believed to be very beneficial, providing a new approach to qualitative studies. Especially outstanding here is the visualization power of graphs and their capacity to capture certain relations. In contrast, we are also aware of the limitations of this methodology and we believe that some strategies should be applied in order to enhance its functionalities. An example would be the fact that with the original data base used in this research, hierarchies among plans and stakeholders are dismissed. This type of information should be captured in future graphs to better adapt outcomes from network analysis to the reality.

The generalization of results coming out from this thesis is expected to be feasible to other areas in NW Mediterranean. However, the methodology implemented is believed to lead to proper outcomes in a broader scope (in terms of different geographic contexts, but also referring to a wide range of disciplines).

# References

- Ballinger, R., Pickaver, A., Lymbery, G. & Ferreria, M. (2010), 'An evaluation of the implementation of the european iczm principles', *Ocean and Coastal Management* **53**, 738–749.
- Bosom, E. & Jimenez, J. A. (2011), 'Probabilistic coastal vulnerability assessment to storms at regional scale – application to catalan beaches (nw mediterranean)', *Natural Hazards and Earth System Sciences* **11**, 475–484.
- Ernstson, H., Sörlin, S. & Elmqvist, T. (2008), 'Social movements and ecosystem services - the role of social network structure in protecting and managing urban green areas in stockholm', *Landscape and Urban Planning* **81**, 46–55.
- Flannery, W., Lynch, K. & Cinnéide, M. O. (2015), 'Consideration of coastal risk in the irish spatial planning process', *Land Use Policy* **43**, 161–169.
- Gibbs, M. T. (2015), 'Coastal climate risk and adaptation studies: The importance of understanding different classes of problem', *Ocean and Coastal Management* **103**, 9–13.
- Guillén, J. (2008), Riskcat: Els riscos naturals a catalunya, Consell Assessor per al Desenvolupament Sostenible, Departament de la Vicepresidència, Generalitat de Catalunya.
- IDESCAT (2016), 'El municipi en xifres', <http://www.idescat.cat/>. [Online: Accessed 02-May-2016].
- Morrow, B. H. (2009), Risk behavior and risk communication: synthesis and expert interviews, PhD thesis, SocResearch Miami.
- Newman, M. (2010), *Networks, An Introduction*, Oxford University Press.
- Page, S. E. (2011), *Diversity and complexity*, Princeton University Press.
- Pahl-Wostl, C. (2009), 'A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes', *Global Environmental Change* **19**, 354–365.
- Parcerisas, L. (2012), 'Cambios en los usos del suelo en el maresme, provincia de barcelona (1850-2007)', *Ciudad y Territorio* **173**, 511–525.
- Reis, J., Stojanovic, T. & Smith, H. (2014), 'Relevance of systems approaches for implementing integrated coastal zone management principles in europe', *Marine Policy* **43**, 3–12.
- Roca, E. (2008), Bringing Public Perceptions in the Integrated Assessment of Coastal Systems, PhD thesis, Institute of Environmental Science and Technology - UAB.
- Roca, E. & Villares, M. (2013), 'Reforzar la resiliencia socioecológica de los destinos turísticos: el caso de la badia de roses (costa brava)', *ACE: Architecture, City and Environment = Arquitectura, Ciudad y Entorno* **9**, 493–524.

- Roca, E., Villares, M., Oroval, L. & Gabarró, A. (2014a), 'Public perception and social network analysis for coastal risk management in maresme sud (barcelona, catalonia)', *Journal of Coastal Conservation* **19**, 693–706.
- Roca, E., Villares, M., Oroval, L. & Gabarró, A. (2014b), 'The social dimension of coastal risk landscapes'.
- Rockström, J. & Klum, M. (2012), *The Human Quest: Prospering within planetary boundaries*, Bokförlaget Langenskiöld.
- Sánchez-Arcilla, A., Mössö, C., Sierra, J. P. & Prat, M. C. (2012), La variabilitat climàtica i la costa catalana., in J. E. Llebot, ed., '2n informe sobre el canvi climàtic a Catalunya', Consell Assessor per al Desenvolupament Sostenible, Departament de la Vicepresidència, Generalitat de Catalunya, pp. 343–371.
- Wong, P. P., Losada, I. J., Gattuso, J.-P., Hinkel, J., Khattabi, A., McInnes, K. L., Saito, Y. & Sallenger, A. (2014), Coastal systems and low-lying areas, in 'Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change', pp. 361–409.

# Acronyms

**ACA** Agència Catalana de l'Aigua.

**ADIF** Administrador de Infraestructuras Ferroviarias.

**AUTP** Autoridad Portuaria.

**CAMCAT** Pla especial d'emergències per contaminació de les aigües marines a Catalunya.

**CHE** Confederación Hidrográfica del Ebro.

**DGC** Dirección General de Sostenibilidad de la Costa y el Mar.

**DGOTU** Direcció General d'Ordenació del Territori i Urbanisme.

**DGPESCA** Direcció General de Pesca i Afers Marítims.

**DGPORTS** Subdirecció General de Ports i Aeroports.

**E MAR** Estrategia Marina de la demarcación marina levantino-balear.

**EACCC** Estrategia de Adaptación al Cambio Climático de la Costa Española.

**ESCACC** Estratègia Catalana d'Adaptació al Canvi Climàtic.

**ICZM** Integrated Coastal Zone Management.

**INUNCAT** Pla d'emergència especial per inundacions de Catalunya.

**LC** Ley de Costas.

**MSL** Mean Sea Level.

**N/A** No Answer.

**NW** Northwest.

**OCC** Oficina Catalana del Canvi climàtic.

**OECC** Oficina Española de Cambio Climático.

**PAEM** Plans d'Actuació d'Emergència Municipal.

**PAM** Programa d'Actuació Municipal.

**PAUT** Pla d'Autoprotecció Municipal.

**PDUSC** Plans directors del sistema costaner.

**PGDCFC** Pla de gestió del districte de conca fluvial de Catalunya.

**PHE** Plan Hidrológico del Ebro.

**PNACC** Plan Nacional de Adaptación al Cambio Climático.

**PORTCAT** Pla de Ports de Catalunya.

**POUM** Pla d'Ordenació Urbanística Municipal.

**PRIBE** Plan Ribera.

**PROCICAT** Pla territorial de protecció civil de Catalunya.

**PROTCIVIL** Protecció Civil de Catalunya.

**SEA** Strategic Environmental Assessment.

**UPORTE** Usos Portuarios de los Puertos del Estado.