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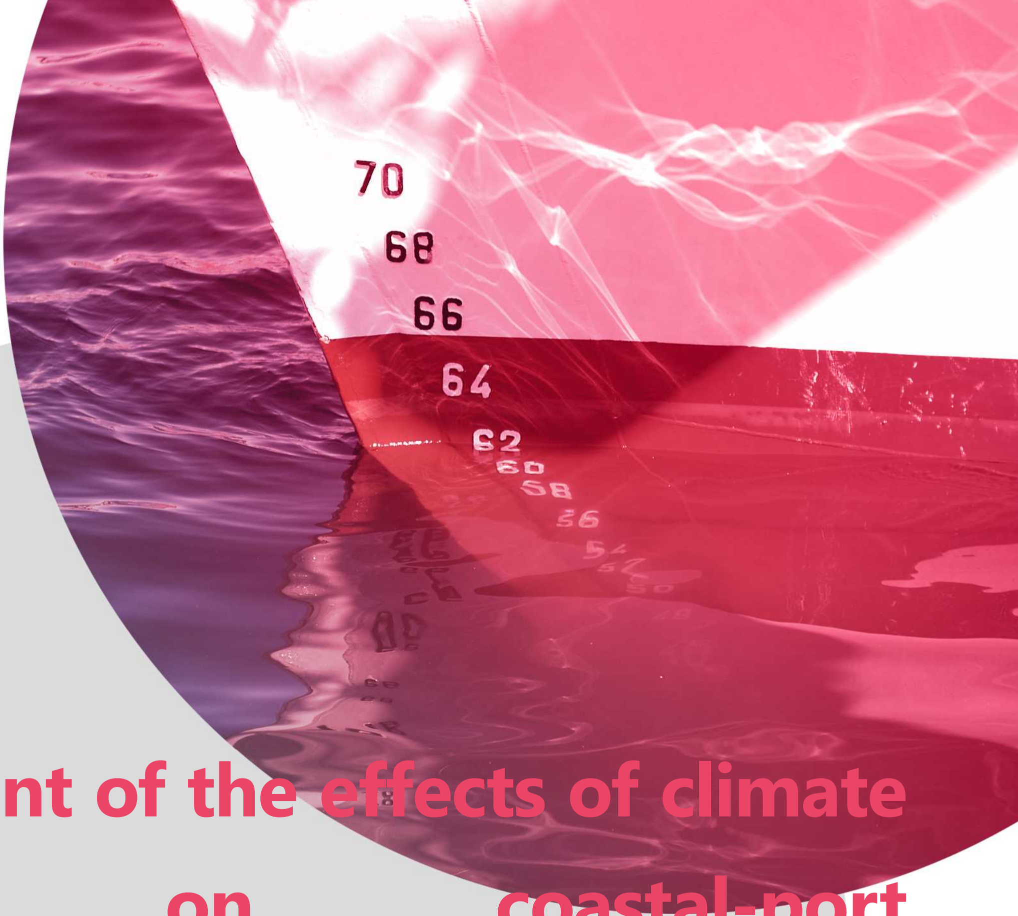

Assessment of the effects of climate change on coastal-port environments

T2.3. Analysis of the effects of climate change on coastal areas

Project – E 2.3.1

30th September 2020

Executive Summary

The European Union (EU) Strategy on Adaptation to Climate Change, launched in 2013, has encouraged all EU Member States to adopt comprehensive adaptation strategies, including also cross-border issues (EC, 2013c). The evaluation of the EU Adaptation Strategy undertaken by the European Commission (EC) showed that the EU Strategy on Adaptation to Climate Change has stimulated some actions on cross-border climate risks between Member States, in particular river basins and Alpine areas, but further action is needed (EC, 2018d). It reiterates the relevant role that transnational (as well as cross-border and interregional) programmes, co-financed by the Cohesion or Regional Policy, play in promoting cooperation projects on CCA, including those developed in the frame of the EU macro-regional strategies. Furthermore, Climate-ADAPT supports cooperation across European countries and regions by fostering exchange of knowledge and experiences and supporting the setting-up of transnational governance structures to jointly cope with common challenges.

Within the institutional framework described above, each country in the SUDOE area has developed a general strategy for adaptation to climate change. It must be highlighted that countries in the SUDOE area have significant socio-economic activity on the coast (tourism, fishing, navigation, etc).

This deliverable addresses the activities carried out in the WP2, which consists of the identification and analysis of the possible effects of climate change on coastal-port environments, both in terms of what may affect their port infrastructure and operations, and in the possible effects it may have on nearby coastal areas.

The main objectives of this WP are the definition of the critical parameters that will be affected by climate change (e.g. wave height, wind speed, etc.) and the limit values or thresholds that must not be exceeded in order to continue port operations safely.

This deliverable particularly addresses the identification of the climate variables that have a greater impact on port infrastructure and operations and constitutes the main input to WP 3, which will model the effects of climate change on coastal-port environments at a local and regional scale. Finally, this deliverable addresses the identification of the main vulnerabilities to climate change for each of the case studies.

It must be noticed that the deliverable is mainly focused on port operations and infrastructures, as ports play a crucial role in the local economies. This is the first time that the adaptation of ports to the climate change effects is addressed with a

cooperative and cross-border vision. It is expected that the results of ECCLIPSE will be a referent for the rest of European ports.

This deliverable is structured in seven chapters: Chapter 1 provides an introduction to the ECCLIPSE project and main objectives. Chapter 2 covers the scope and motivation of this deliverable. Chapter 3 provides an overview of coastal activities associated to blue economy, identifying the main hazards that can affect these sectors, as well as those affecting the coastal strip. Ports, which have a specific idiosyncrasy, are covered in Chapter 4, focusing on both the infrastructures and the operations related to the activity in the port. Chapter 5 describes the three areas of study that will be covered in ECCLIPSE project: Aveiro, Bordeaux and Valencia. Chapter 6 provides a summary of the local evaluation of climate-related hazards for each of the study areas, covering the coastal area and port area. Finally, chapter 7 provides lessons learned and concluding remarks.

Disclaimer

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Abbreviations

EU	European Union
GVA	Gross value added
IPCC	Intergovernmental Panel on Climate Change
GPMB	Grand Port Maritime de Bordeaux
WP	Work Package
RCP	Representative Concentration Pathways
SSP	Shared Socio-economic Pathways
IAPH	International Association of Ports and Harbours
UNCTAD	United Nations Conference on Trade and Development
AAPA	American Association of Port Authorities

1 PROJECT OVERVIEW

1.1 Motivation

Ports are crucial to a national economy and their importance will increase due to the expected increase in international trade. As an example, the Port of Valencia provides the Valencian economy with a Gross Added Value of 2,500 million euros, a figure equivalent to 2.39% of the Gross Domestic Product of the Valencian Community and generates 38,866 jobs that represent 2.09% of its employment.

Ports are susceptible to the effects of climate change such as variations in waves, sea level rise and heat waves. In this context, the ports of the SUDOE space face the common challenge of adapting to the effects of climate change to avoid having to stop operations. With today's just-in-time production models, the total or partial closure of ports would affect industry and freight distribution centres.

On the other hand, it should be noted that the effects of climate change in the Mediterranean ports of the SUDOE space are different from those of other ports located in the Atlantic Ocean or in the Cantabrian Sea, so it is important to cooperate and seek synergies between regions facing similar challenges. ECCLIPSE aims to respond to a need that cannot be addressed solely from a national perspective.

It is therefore necessary for ports to implement effective climate change adaptation strategies. Such strategies require tools that allow a deep understanding of the impacts of climate change at a local scale, as opposed to current models that due to their globality and wide temporal range are not effective in decision-making.

ECCLIPSE will analyse the impact of climate change in ports, develop tools and models for early prediction, contribute to raising awareness of the impact of climate change and define transnational strategies for prevention and action in the SUDOE space that will can minimize their effects.

1.2 ECCLIPSE Objectives

The objective of ECCLIPSE is to develop a common framework for assessing the impacts associated with climate change and the adaptation to such impacts of ports in the SUDOE space.

The main project results will be:

• The development and implementation of a common methodology will make it possible to assure the consistency of the results to be obtained for each port by using the same scientific and technical criteria so that the conclusions drawn for the entire port network are consistent. This also makes it easier to extend the application to other

European ports.

• ECCLIPSE will provide the mechanisms for designing and implementing the measures to adapt ports to climate change. These measures will have a common scientific basis for the whole European port network.

• Finally, the results of the climate projections will be stored in a climate database by port, which will allow the study of the evolution of the climate change impact in specific locations when planning and designing new port infrastructures

2 INTRODUCTION

The European Union (EU) Strategy on Adaptation to Climate Change (EC, 2013c) aims to make Europe more climate resilient. Taking a coherent approach by complementing the activities of Member States (MS), it promotes adaptation action across the EU, ensuring that adaptation considerations are addressed in all relevant EU policies, i.e. mainstreaming, promoting greater coordination, coherence and information and good practice sharing.

Figure 1 EU Strategy in a Nutshell
Source: Climate-Adapt. European Commission[1]

The countries that are part of the SUDOE area, have adapted a national strategy for adaptation to climate change, although only two of them (France and Spain) have implemented it[2].

[1] https://climate-adapt.eea.europa.eu/eu-adaptation-policy/strategy
[2] https://www.eea.europa.eu/airs/2018/environment-and-health/climate-change-adaptation-strategies

The **South West Europe region** is identified as a 'hotspot' of climate change. This region has already been affected by observed impacts and will likely be increasingly affected by the future impacts of climate change with negative effects across multiple sectors. In particular, the relevant observed and projected climate change and impacts in the SUDOE area are:

Table 1. Climate change related hazards

Climate change related hazard	Evolution compared with the baseline period 1971-2000	Comments
Increase in air temperatures	Annual temperature is further expected to rise between 1.9–2.7°C for RCP4.5 and 3.9–5.4°C for RCP8.5	While periods of extreme high temperatures are projected to become more frequent and severe across the whole continent, Southern Europe will experience the greatest increase
Decrease of precipitation	Projections for the end of century under the RCP8.5 scenario indicate a decrease in mean annual precipitation of up to 40 %	Annual precipitation has decreased by up to 90 mm per decade across the whole peninsula, and particularly in central Portugal
Sea level rise	In line with the global averages	An increase in mean sea level ranging between 1.5 mm/year in the Mediterranean Spanish coasts (with important regional and rate variations up to 3.1 mm/year in Costa Brava over the last 28 years (BAIC, 2018)) and 2 mm/year in the Cantabrian Sea of Spain have been registered in the last 60 years along the Spanish coastlines, and have recently shown an accelerated rate of increase
Droughts	Intense events even under a moderate emission scenario and both in the near (2041–	The Iberian peninsula has already experienced many severe droughts in the past decades, and it is likely to be affected by longer, more frequent droughts.

	2070) and far future (2071–2100)	
Storm surges	Modification in storm patterns, and extreme events will have a direct impact in storm surges	Storm surges has a direct impact in the coastal strip and flooding risk.
Sea surface temperatures	Increase in sea surface temperature expected during this century in all scenarios	Increase in sea surface temperature will have an impact in biodiversity. As an example, in the Mediterranean, this will have a negative impact in Posidonia forests.
Sea water acidification		

Source: Own elaboration based on ETC/CCA Technical Paper 2018/4

The need for adapting the transport system to the impact of climate change has been highlighted since the European Commission's White Paper *Adapting to climate change: towards a European framework for action*[3]. Adaptation actions are focused on transport infrastructure design and management, and are supported jointly by European policies on transport, climate change, regional development and research.

In 2019, extreme weather and climate change policy failures were identified by the World Economic Forum's Global Risk Report as the gravest short to medium-term threats to be dealt with globally. The United Nations Conference on Trade and Development [UNCTAD, 2018] specifically highlighted the urgent need for ports to adapt, along with vital connecting transport infrastructure and global supply-chain networks if significant trade disruption is to be avoided. In 2018, the European Joint Research Centre [JRC, 2018] published two studies highlighting an unprecedented coastal flood risk unless urgent climate change adaptation measures are taken.

Despite the EU's interest in ensuring the resilience of transport infrastructure, only two ports have carried out initiatives to assess the impact of climate change. The port of Cork (Ireland) has investigated risks associated with climate change; this process culminated in the preparation of an Adaptation Strategy for Cork Harbour, focusing on flood management by 2030.

The port of Antwerp has participated in the assessment of climate change in the navigability of the Albert canal. The Albert canal in the eastern part of Flanders

[3] Adapting to climate change: Towards a European framework for action. White Paper. European Commission, 2009

connects the industrial zones around Liege with the harbour of Antwerp. The objective of this case study was to avoid economic damage due to reduced traffic possibilities at the canal (due to very low water discharge from the Meuse river), which are expected to be aggravated in the future because of climate change.

Regarding coastal areas, several impacts due to climate change has been identified in previous studies. Sea level rise can cause flooding, coastal erosion and the loss of low-lying coastal systems. It will also increase the risk of storm surges and the likelihood of landward intrusion of saltwater and may endanger coastal ecosystems. Expected rises in water temperatures and ocean acidification will contribute to a restructuring of coastal ecosystems, with implications for ocean circulation and biogeochemical cycling.

ECCLIPSE project is a cooperative initiative between public institutions, research centres and private companies of three European neighbouring countries for assessing the impact of climate change in port operations and infrastructures. This initiative is co-funded by the Interreg SUDOE program.

The deliverable provides a brief introduction to the potential consequences of climate change and some of the challenges to be addressed. Although the deliverable focuses on climate change impacts in ports, it also addresses those impacts on the most relevant coastal activities in the SUDOE area

3 COASTAL AREAS

This section identifies the coastal activities and facilities in relation with Blue Economy in the region. After an introduction, which includes a literature review, the section is organised as follows: firstly, presents a broad overview of the socio-economic impact of the Blue Economy for the established and emerging sectors selected for this deliverable, at EU aggregated level providing general information according to

Reports of European Commission. Secondly offers an overview of the coastal strip emerging and effects of coastal erosion, flooding and water quality based also in the existing literature. Main hazards affecting the blue economy sectors and coastal strip are identified.

3.1 Introduction

Associated with climate change there are many challenges to be faced in coastal areas. One of them is the impact on socio-economic activity taking in consideration the effects of climate change on coastal-port environments.

The maritime economy is now often referred to as the 'Blue Economy'. It covers all marketable activities linked to the sea. The link between activities and the sea may be explained by the use of marine resources, maritime areas or regions or by the vicinity of these spatial units.

The regions most impacted by the maritime economy are of course the EU's coastal regions which are made up of 446 regions (out of a total of 1,348 NUTS 3 regions — 2018 classification). Almost 45% of the EU population (214 million people) live in coastal regions in 2017 (Eurostat data).

The ocean covers more than 70% of the Earth's surface and ocean and coastal ecosystems provide human beings with considerable economic and environmental services as well as impressive natural capital. Besides the traditional exploitation of living resources (fishing, aquaculture and the processing sector), a broader vision of the Blue Economy can offer important sources of economic development for MS economies and coastal communities in particular.

According to the EU Blue Economy Report (2020) there are seven established sectors that include following: Marine living resources, Marine non-living resources, Marine renewable energy, Maritime transport, Port activities, Shipbuilding and repair and Coastal tourism. The analysis of these sectors is based on the data collected in this report and taking only the direct contribution of the Blue Economy sectors is considered. According to the most recent figures, the established sectors of the EU Blue Economy directly employed over 4.9 million people, generated €749.7 billion of turnover increased by 12 % (€670.9 billion in 2009) and €218.3 billion of gross value added in 2018. The evolution of the Blue Economy has been significantly influenced by general macroeconomic developments, in particular the global financial and economic crisis of 2008-2009. High growth rates can be observed in traditional sectors.

Additionally, the Blue Economy emerging and innovative sectors include some Marine renewable energy (i.e. Ocean energy, floating solar energy and offshore hydrogen generation), Blue bioeconomy and biotechnology, Marine minerals, Desalination, Maritime defence, and Submarine cables. These sectors offer significant potential for growth and jobs, especially in renewable energies where the EU is in the lead hosting 70 % of global ocean energy (wave and tidal) installed capacity in its waters. The Maritime defence sector accounts for over 177 000 jobs and within Blue bioeconomy sector, the algae sector generated an estimated turnover of over €350 million. Desalination continues to be a key sector for those countries that are more likely to suffer water shortages (e.g. Spain), not least as a result of climate change, even if with important side effects (brine, energy consumption etc.). (Commission. 2020. P.11)

This section includes a review of 3 sectors, costal tourism, marine living resources (aquaculture and fishing) and blue energy, which has an economic impact in coastal areas and a description of how climate change could affect them.

The deterioration of the seas may have disastrous consequences through not only the impact of climate change and the increasing costs to mitigate its consequences, but already today as a result of nutrients and marine litter on the surface, water column and seabed. In fact, marine litter is already generating costs and lost revenues in sectors like fishing, aquaculture, tourism and government estimated at almost €11 billion a year[4].

The negative economic impact of climate change in the form of coastal flooding in the EU is estimated to reach between €12 billion and €40 billion a year by 2050 and to affect between 500,000 and 740,000 EU citizens, depending on the scenario. (Commission. 2019. P.9)

The Blue Economy is interconnected with many other activities in the economy and its impact goes beyond the sectors mentioned above. Also, its importance varies significantly across the EU. Some case studies in this deliverable illustrate some of the wider scope of the Blue Economy. One of them in Spain, the analysis of port of Valencia shows economic impact of port activity: Valencia port provide 2 out of every 100 jobs in the whole of the Valencia region, while 15.000 direct and indirect jobs are generated by the activity of the Grand Port Maritime de Bordeaux (GPMB)

Although not enough information is currently available to comprehensively estimate indirect and induced effects in blue economy.

A delineation of the Blue Economy largely depends on the sectors included and the extent to which indirect upstream and downstream effects can be identified and measured. Hence, deciding what sectors and activities to include when analysing the current state and size of the Blue Economy, is an important first step.

[4] Blue Economic Report (2019)

3.2 Coastal Tourism

Coastal tourism covers beach-based tourism and recreational activities, e.g. swimming, sunbathing, and other activities for which the proximity of the sea is an advantage, such as coastal walks and wildlife watching. Maritime tourism covers water-related activities and nautical sports, such as sailing, scuba diving and cruising. According to Blue Economy Report (2020), Coastal tourism also refers to maritime tourism and is broken down into three activities: accommodation, transport and other expenditures.

As it encompasses various economic activities, and the link with oceans and/or coastal regions is sometimes weak, Coastal tourism tends to outweigh the other sectors of the Blue Economy in terms of turnover, value added and employment. Overall, Coastal tourism accounted for 62 % of the jobs, 41 % of the GVA and 34 % of the profits in the EU Blue Economy in 2018. (Figure 2~~Figure 2~~). The sector has grown substantially over the analysed period (Commission. 2020. P.103).

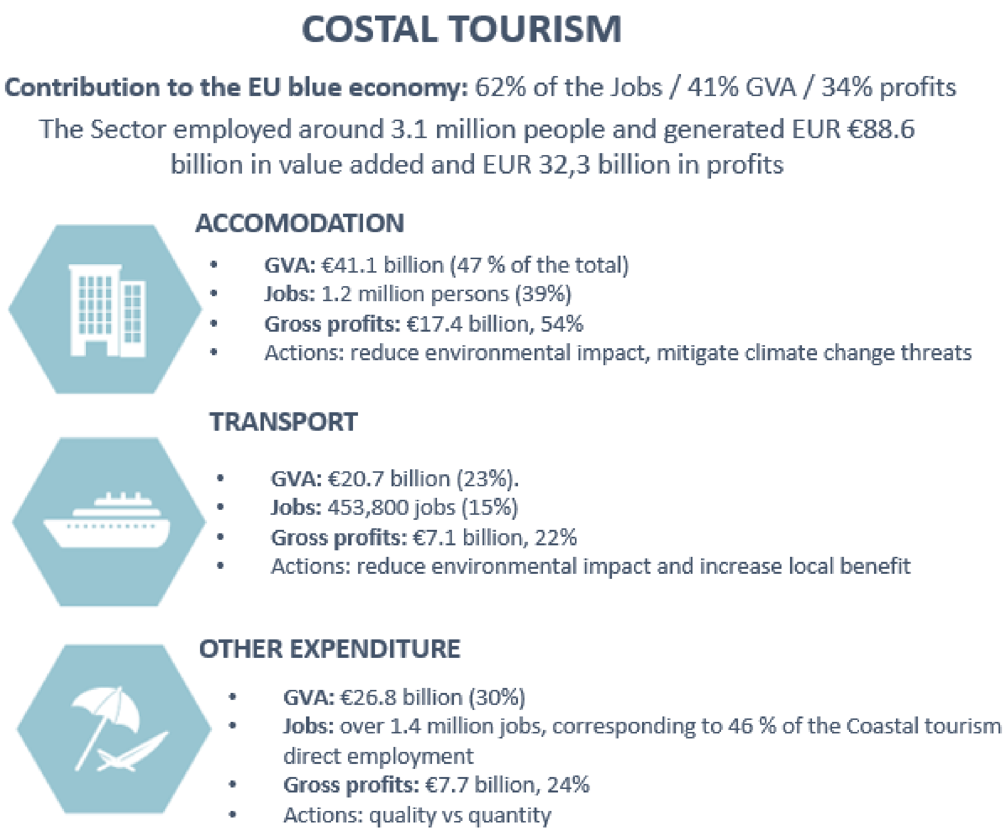


Figure 2 Contribution Costal Tourism to the EU Blue Economy, 2018
Source: Own elaboration with information from Blue Economy Report 2019 and 2020, European Commission

GVA generated by the sector amounted to just under €88.6 billion, a 20 % rise compared to 2009. Gross operating surplus was valued at €32.3 billion (+44 %

compared to 2009). Turnover amounted to €249.6 billion, 18 % more than in 2009. Around 3.1 million people were directly employed in the sector in 2018 (up by 13.5 % compared to 2016) and personnel costs reached €56.4 billion, up from €51.5 billion in 2009, amounting to an average wage of €18 210 in 2018, a 10 % increase from €16 600 in 2009. The sector was impacted by the global economic and financial crisis, which saw a gradual decrease in employment over the period 2009 to 2015. (Commission. 2020.P.101)
According to Blue Economy Report (2020) impact of Costal Tourism by Member State, as shown in Figure 3~~Figure 2~~, Spain leads Coastal tourism with 24 % of the jobs and 27 % of the GVA, followed by Greece and Italy. The sector is recovering and growing in 2018.

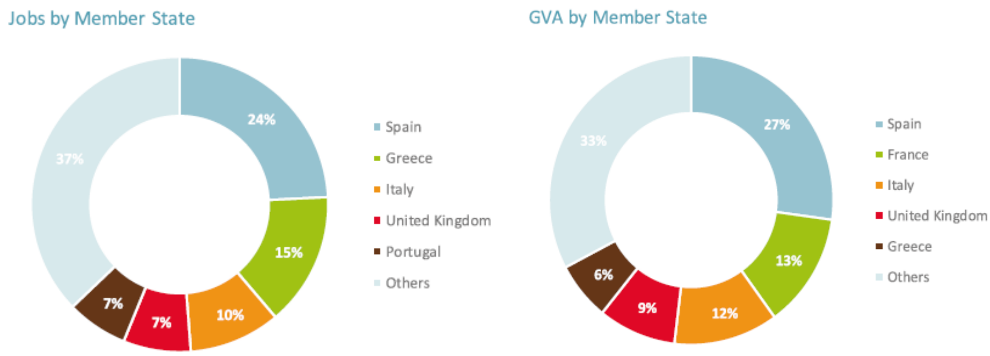


Figure 3~~2~~ EU Coastal tourism by Member State, 2018

Source: Blue Economy Report 2020, P.101

Challenges:

As mentioned above, tourism plays an important role in the economy of coastal areas. However, coastal tourism depends on natural conditions. Current weather and climate conditions favour the Mediterranean regions in the summer. However, in the future this region will become less attractive due to drought and heat waves, which will raise temperatures above the heat comfort zone, as well as the general scarcity of water. On the other hand, regions in the Atlantic might become more attractive for tourism. Summers there will become dryer with higher temperatures.
If not managed properly, it is widely recognized that tourism can bring about negative environmental externalities. Coastal and maritime tourism depend highly on good environmental conditions and, in particular, on good water quality. Any maritime or land-based activity deteriorating the environmental can negatively affect tourism. Coastal areas may also be directly or indirectly affected by several climate change related impacts, such as, flooding erosion, saltwater intrusion, increase in air and seawater temperatures and droughts.

Various studies analyse the behaviour of tourists in relation to possible climate change scenarios. For example, Coombes & Jones (2010) focuses on impact of factors such as variation in atmospheric temperatures or rising sea levels on the demand for beach areas and participation in different recreational activities (e.g. bathing, bird watching, walking. Rodrigues et al. (2016) analyse the preferences of divers in relation to various diving experiences, differentiated by attributes such as the number of geomorphological elements found underwater or different levels of presence of species vulnerable to climate change. Dubois et al. (2016) study the preferences of French tourists in relation to climate, including the evaluation of their tolerance to heat waves and rainy conditions. Parsons et al. (2013) performs a user satisfaction analysis of beach areas in Delaware Bay (US East Coast) based on changes in the width of beaches, using the methods of travel cost and contingent valuation.

The results of a questionnaire conducted on 537 individuals indicate that the loss of beach width can result in a reduction in the quality of the experience for 67% of individuals and the number of trips to that destination (31%), while the width extension can result in an improvement in the quality of experience (42%) and, to a lesser extent, an increase in travel (18%).

Table 2 Changing beach width and effect on quality of experience and number of trips

KPI	Quarter width reduction	Twice the width increase
Quality of the experience		
Without effect (%)	33	49
Worsening (%)	67	9
Improvement (%)	<1	42
Number of journeys		
Without effect (%)	69	80
Less journeys (%)	31	2
More journeys (%)	0	18

Source: Own elaboration based on Parsons et al. (2013)

Also, Jimenez et al. (2016) present a relationship between beach width ranges and their level of ability to provide recreational function. Specifically, this capacity is classified as "Optimal" (for a width level greater than 40 m), "Medium" (between 20 and 40 m inclusive) and "Low" (less than 20 m)

The project "Tool-supported policy development for regional adaptation" (ToPDAd), financed in the context of the EU's Seventh Framework Programme (FP7), analyses, among other sectors, the impact of climate change on beach tourism[5]. One of the main results refers to the projection of the change in the number of nights spent in summer for the period 2010-2085 in various European regions, with and without adaptation strategies.

As an example, Figure 4~~Figure 4~~ presents the results for the province of Valencia, based on the RCP (Representative Concentration Pathways) emission scenarios, specifically RCP4.5 atmospheric CO2 concentration in the order of 538 ppm in 2100) and RCP 8.5 (936 ppm in 2100) (IPCC, 2013). In addition, both scenarios are complemented by the SSP4 [6]scenarios (SSP refers to Shared Socio-economic Pathways).

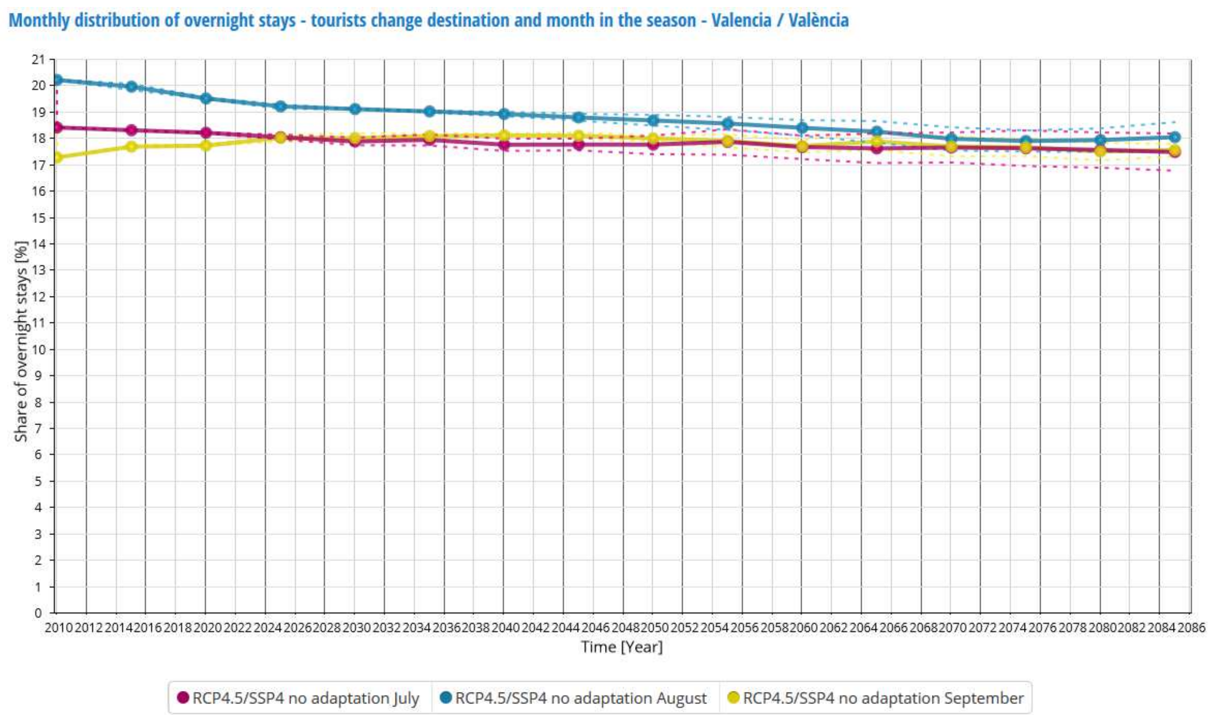


Figure 4 Monthly distribution of overnight stays - tourists change destination and month in the season

Source: http://topdad.services.geodesk.nl/web/guest/interactive-tool

This projection analyses the possibility of tourists to change the period or destination of beach vacations due to the increase of atmospheric temperatures. The results indicate a possible decrease in the number of nights spent in the province of Valencia

[5] http://topdad.services.geodesk.nl/web/guest/interactive-tool

[6] SSP4 refers to a mitigation scenario based on the potential development of low carbon technologies. However, at the adaptation level, it is characterized by a high level of inequity between countries and population groups in terms of political power and economic opportunities.

during the month of August, reaching 1% for the RCP4.5 and RCP8.5 scenarios in 2050 compared to 2020.

3.3 Aquaculture and fishing

The Marine living resources sector encompasses the harvesting of renewable biological resources (primary sector), their conversion into food, feed, bio-based products and bioenergy (processing) and their distribution along the supply chain. According to Blue Economy Report (2020), Marine living resource sector comprises three subsectors that are further broken-down into the following activities: **Primary sector:** Capture fisheries (small-scale coastal, large-scale and industrial fleets) and Aquaculture (marine, freshwater and shellfish); **Processing of fish products**: Processing and preservation of fish, crustaceans and molluscs; Prepared meals and dishes, Manufacture of oils and fats and Other food products and **Distribution of fish products:** Retail sale of fish, crustaceans and molluscs in specialised stores174 and Wholesale of other food, including fish, crustaceans and molluscs.

The EU is the fifth largest producer of fishery and aquaculture products, covering around 3% of global production. The processing and distribution of fish products is heavily dependent on the supply of raw materials from the primary sector. Increased internal demand for seafood products and stagnation in the primary sector make these activities increasingly dependent on imports from third countries.

Capture fisheries production has increased and may have the capacity to do so further, in part due to the improved status of fish stocks and increased fishing opportunities, together with higher average market prices and reduced operating costs. The economic performance is expected to continue to improve as fish stocks recover and capacity continues to adapt. EU Aquaculture production in volume has stagnated over the last decades even if its value has increased. Considering the increasing demand of seafood products in the EU, it seems realistic to expect growth of in EU aquaculture products.

Overall, the contribution of Marine living resources to the EU Blue Economy in 2018 was 11.5% of the jobs, 9.6% of the GVA and 9% of the profits. Overall, the economic performance of the sector has improved and is better off than in 2009.

Overall, Marine living resources sector accounted for 11.5 % of the jobs, 9.6% of the GVA and 9% of the profits in the EU Blue Economy in 2018. (Figure 5~~Figure 5~~). The sector has grown substantially over the analysed period (Commission. 2020. P.66).

MARINE LIVING RESOURCE

Contribution to the EU blue economy: 11.5% of the Jobs / 9.6% GVA / 9% profits

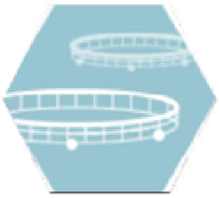
The Sector employed around 573,300 people and generated EUR €21 billion in value added and EUR 8.4 billion in profits

PRIMARY SECTOR

- **GVA:** €6.3 billion (30% of the total)
- **Jobs:** 217,854 persons (38%)
- **Gross profits:** €2.6 billion, 32%
- Actions: reduce fishing capacity and improve status of stock

PROCESSING OF FISHING

- **GVA:** €6,09 billion (29%).
- **Jobs:** 143,325 (25%)
- **Gross profits:** €2.1 billion, 26%
- Actions: guarantee adequate supply of quality raw materials



DISTRIBUTION

- **GVA:** €8.6 billion (41%)
- **Jobs:** 212,121 over jobs, corresponding to 37%
- **Gross profits:** €3,5 billion, 42%
- Actions:

Figure 5 Contribution Marine Living to the EU Blue Economy, 2018
Source: Own elaboration with information from Blue Economy Report 2019 and 2020, European Commission

According to Blue Economy Report (2020) impact of Marine living resource by Member State, as shown in Figure 6. Spain leads the Marine living resources sector with 20 % of the jobs and 17 % of the GVA. Moreover, Spain generates the most jobs in all three sub-sectors apart from processing, where the United Kingdom takes the lead.

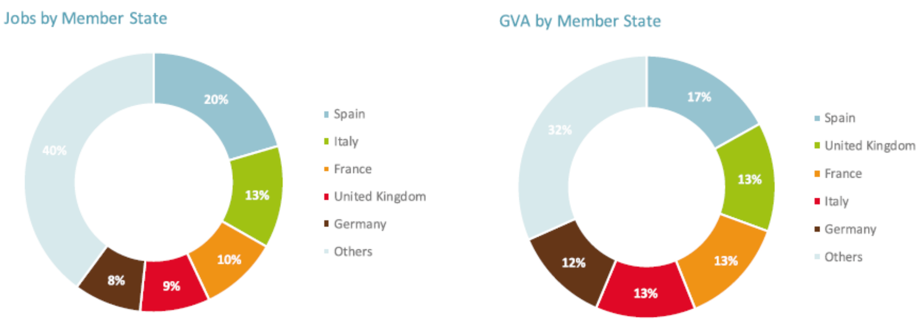


Figure 6 EU Marine living resource by Member State, 2018
Source: Blue Economy Report 2020, P.67

Challenges:

Fishing and aquaculture are already experiencing effects of the stress on marine ecosystems resulting from overfishing and will be further affected by climate change. Sea surface temperature increase in the last decades has already had visible effects on marine ecosystems, with species moving north. Changes in temperature are also likely to increase susceptibility of fish to diseases, reducing populations. Impacts of other changes, and the interactions between these, such as changes in salinity and acidification, as well as losses of coastal ecosystems, are not yet fully understood.

Shellfish

Shellfish are filtering animals that obtain their food from the phytoplankton in the seawater. The availability of phytoplankton is related to the wind regime, water temperature and coastal outcrops, and due to the representativeness of the mussel in terms of its production, this group of species is considered very vulnerable to the effects of climate change in the Valencian Community.

Wild fish and fish farms

Species such as sea bass require colder waters than sea bream, in waters where the average temperature is already high enough, these species will find it more difficult to reproduce and/or grow to commercial sizes, decreasing their profitability.

Regarding aquaculture, farms are vulnerable to the potential increase of storms, which can damage floating structures causing nets to break and the consequent escape of fish, causing economic losses for the company and impacts on local species and fisheries.

Microalgae

The production of microalgae must be carried out in previously analysed and selected areas according to various limiting factors for the growth of these species. Two types of factors must be considered: internal and external. The relevance associated with each factor will be conclusive to determine the risks associated with the development of this type of technology, on a pilot or industrial scale, in a specific location.

Thus, microalgae production will be more or less vulnerable depending on the suitability of the area where the microalgae of interest is chosen to be grown. Therefore, to select the most suitable area to cultivate microalgae and in the case of the Valencian Community, the following factors should be taken into account:

Temperature

For microalgae cultivation, small temperature variations are preferable throughout the year, between the highest summer values and the lowest winter values. A temperate climate is recommended, with temperatures that are not extreme.

Each microalgae presents an optimal temperature for its growth, in which the productivity of its crops will reach higher values. As a general rule, they tend to tolerate a wide range of temperature without cell death, although their productivity is significantly affected. In order to carry out a good control of the culture, it is necessary to know the optimal temperature of growth of the lineage in question, as well as its lower and upper limits.

Rainfall

The rainfall levels of an area are influential due to high values of this parameter usually correspond to low values of irradiance, and therefore productivity.

In addition, this factor should be considered when there are open reactors in the installation, which could have problems of dilution of the crop in case the area of implantation is characterized by high levels of rainfall.

pH

The pH range in which microalgae can be grown varies considerably depending on the strain. Normally, they are capable of developing in pH ranges of a certain amplitude, although for each of them there is an optimal pH value, in which their productivity is maximum. Small variations in pH, even if they do not cause the death of the crop, can cause substantial reductions in productivity.

Salinity

Microalgae can be found in any type of ecosystem: hypersaline, saline, brackish and fresh waters. Each of the strains that are intended to be cultivated may have different saline requirements. The water of the place where the culture is established must have some characteristics of salinity according to the own demand of the strain to be cultivated. If this is not the case, it would imply an increase in costs due to the addition or removal of salt from the environment.

The CERES project (Climate Change and European Aquatic Resources)[7] provides a cause-and-effect understanding and management responses on how climate change will influence European fish and shellfish resources and the economic activities that depend on them. A summary of adaptation measures needed in light of the ongoing and projected changes in the climate, highlights both similarities and differences between fisheries and aquaculture. An integrated approach, encompassing both top-down demands (by governance) and bottom-up responses (by stakeholders) and covering technology, economics, governance and societal and industrial behaviours, is required to tackle the challenges posed by climate change to both sectors (Figure 7~~Figure 7~~) (Commission 2020, p.35)

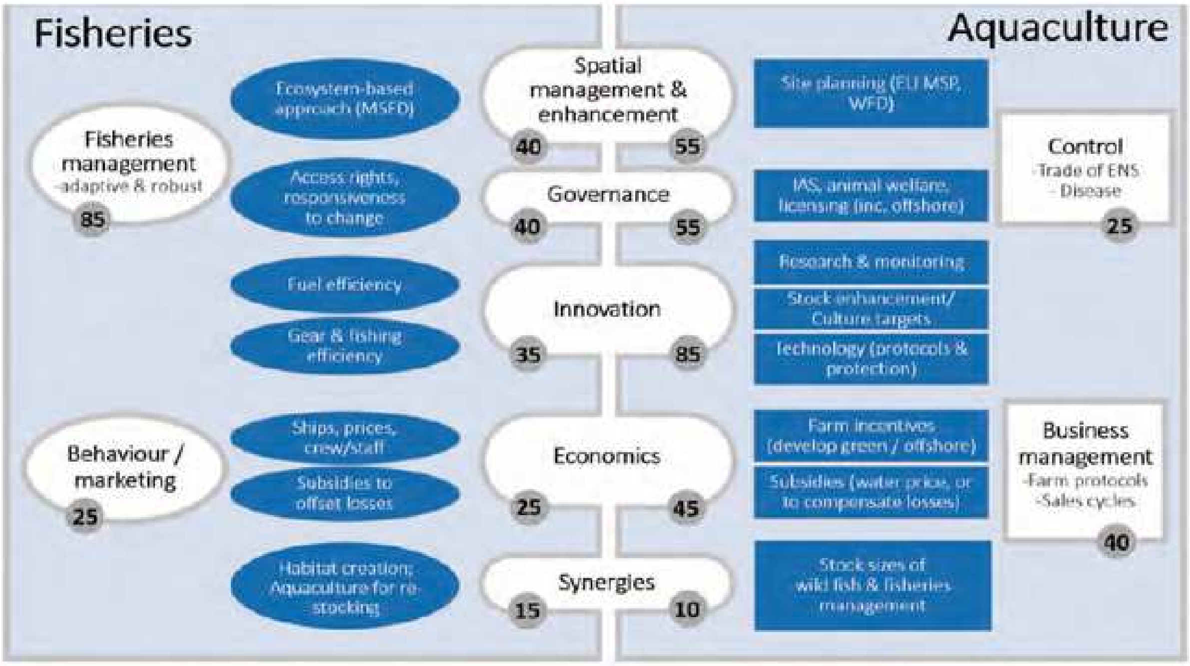


Figure 7 Measures needed for transformative adaptation of the fisheries and/or aquaculture sectors in light of ongoing climate change, 2020
Source: Blue Economy Report 2020, European Commission, P 35

[7] CERES project is fund under the EU Horizon 2020 programme https://ceresproject.eu/.

3.4 Coastal strip

The SUDOE coastal region vary widely in terms of coastal ecosystems and habitats, catchments, and sea areas. They include coasts exposed to the open ocean, as well as important estuaries and deltas.

Among others, the main climate change hazards affecting the coastal area are the rise of the sea level, the higher frequency of storms, the increase in sea surface temperature. In terms of effects, these can vary between coastal erosion, seawater intrusion in marshes, species migration, modifications in water quality and salinity or the decrease of pH of seawater.

The erosion of beach areas due to climate change is presented as a matter of concern, which may have negative implications in certain economic sectors and inhabited areas. In particular, Spain presents a great concentration of urban and semi-urban spaces on its coast, which increases the socio-economic vulnerability of the populations that live in these areas, as well as restricts the possibility of the natural adaptation of beaches due to the presence of permeable urban spaces very close to the coast line. In addition, about a quarter of the Portuguese coast shows symptoms of instability due to erosion of cliffs or low-lying sections, particularly in Algarve. In central Algarve, retreat rates of 2.27 m/year have been observed (Proença et al., 2011).

This implies a greater adaptive response based on coastal protection and accommodation measures, which can mean high costs and non-guaranteed effectiveness.

This chapter focuses on climate change hazards relating to sea level rise and coastal storms, which can influence the effects of coastal erosion and increased frequency of coastal flooding.

3.4.1 Coastal erosion

Coast erosion is the process of wearing away material from a coastal profile due to imbalance in the supply and export of material from a certain section. It takes place in the form of scouring in the foot of the cliffs or dunes or at the subtidal foreshore. The rate of erosion is correctly expressed in volume/ length/time, e.g. in m3/m/year, but erosion rate is often used synonymously with coastline retreat, and thus expressed in m/year.

Understanding coastal erosion processes requires an insight into all the factors that interact along the shoreline and an awareness of different time scales. On geological time scales, coastal evolution in sedimentary environments is governed by the demand and supply of sediments. Sediment demand of a coast is determined by the rate of relative sea-level rise and by the morphology of the coastal plain. Sediment supply is determined by the availability of sediment and by the transport capacity of wind and water. The balance between sediment demand and supply drives the evolution of the coast: when supply is greater than demand, the coast will grow seaward, when demand equals supply, the coast will stay in place, and when the supply is insufficient, the coast will tend to retreat.

When the sea level rise, the coastline could be stable or even grow seaward, if there is sufficient sediment supply. It also shows that even without coastal erosion the coastline can retreat when the sea level rises and causes submergence of the coast. The adverse impacts of coastal erosion most frequently encountered in the SUDOE area can be grouped in three categories:

- coastal flooding as a result of complete dune erosion,
- undermining of coastal protection associated with foreshore erosion and loss of buffering coastal habitats,
- retreating cliffs, beaches and dunes causing loss of lands of economic and ecological values

In addition, the erosion of the dune barrier due to both extreme weather events and anthropic action intensifies the effect of climate change in coastal erosion, to the extent that the dune barrier significantly contributes to protect and maintain the stability of the beach and the area behind.

Several EU funded projects [8]have demonstrated that severe and extreme storms are among the main drivers of coastal erosion: about 70 % of the analysed case studies identified storms as the most relevant factor governing the observed erosive processes. Storminess drivers are particularly relevant along the coast of the Atlantic Ocean. Besides coastal erosion, storm waves and storm surges may also induce other effects: dune erosion, flooding, overwash, and in general, alteration or loss of littoral habitats.
If we look at what happens during a storm only a part of the long-term processes is visible. On a sandy coast, for example, a combination of high tide and strong winds pushes up the sea water level, exposing the beach and dunes to heavy attack by the

[8] 'Responding to the risk from climate change on the coast' (Response) see http://www.coastalwight.gov.uk/response/
index.htm; 'Morphological impacts and coastal risks induced by extreme storm events' (Micore) see https://www.micore. eu; 'Concept and science for coastal erosion management' (Conscience) see http://www.conscience-eu.net/index.htm;
'Innovative coastal technologies for safer European coasts in a changing climate' (Theseus) see http://www.theseusproject.
eu; 'Regional action strategies for coastal zone adaptation to climate change' (Coastance) see http://www.coastance.eu.

incoming waves, usually resulting in erosion. Sand is dragged down the slope by the down rush causing erosion of the beach and dunes and undermining of the dune toe. Part of the dune face may collapse, and this slumped sediment will slide downwards where it can be eroded further again by wave-induced processes. The sediment is then transported to the sea where it will settle at deeper water. During a subsequent calmer period, some of the sediment may return to the coast through onshore directed wave-driven and wind-driven transport, usually resulting in accretion in the beach zone. However, longshore currents may also remobilise the sediment, leading to further sediment movement away from the original location.

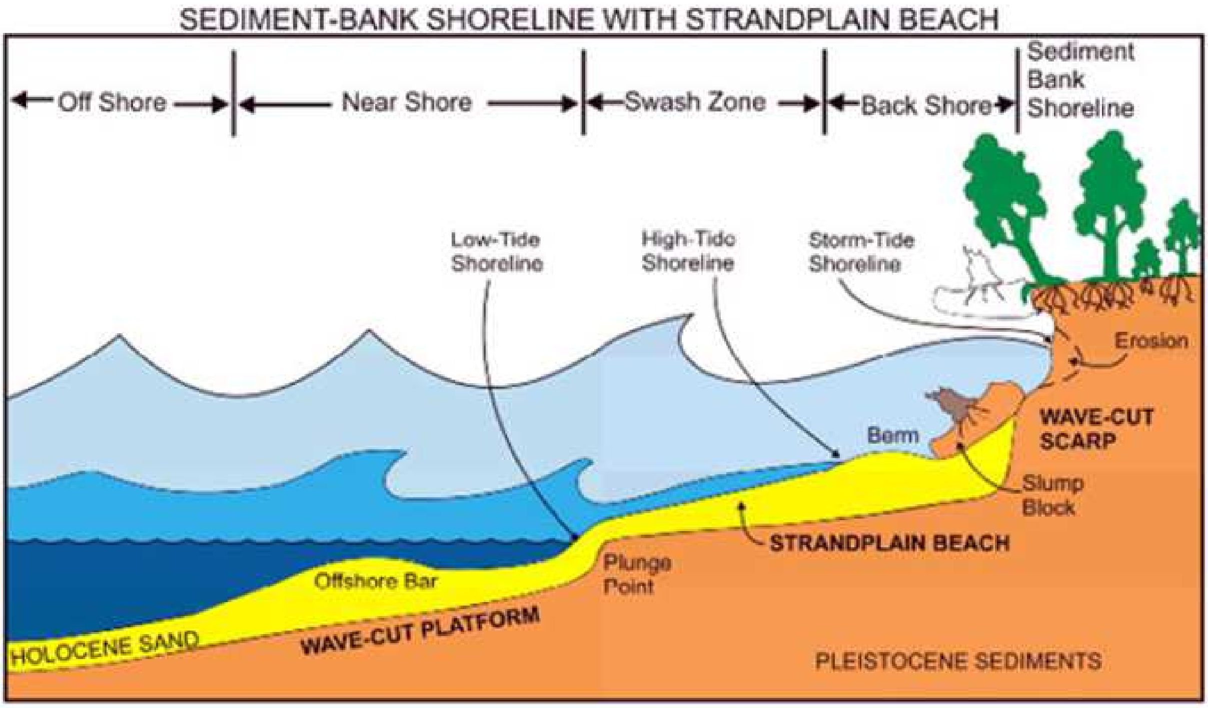


Figure 8 Process of coastal erosion
Source: http://www.deepmapscork.ie

Climate change is likely to increase coastal erosion. Sea levels across the SUDOE area are rising in general, although regional variations exist. Rising sea levels increase sediment demand, as retreating coastline and higher sea levels will raise extreme water levels, allow waves to break nearer to the coast, and transmit more wave energy to the shoreline. Other climate change drivers that may exacerbate erosion rates are increased storminess, higher waves and changes in prevalent wind and wave directions (Marchand, 2010). The combined effect of sea-level rise and other changes in shallow areas such as coastal wetlands and coastal lagoons may cause them to 'drown' (merge into the sea). In coastal areas with barrier islands in front of the coast, such barriers are likely to erode.

In the view of rising sea levels and increasing coastal erosion, the subsidence of coastal land threatens the landward side of the coast. The combined effect of sea-level rise and subsidence is posing a threat to many coastal settlements located in river deltas where the natural process of sediment compaction occurs. A heavy aquifer drawdown may also be the cause of ground subsidence.
Coastal erosion in Europe is responsible for significant economic loss, ecological damage and societal problems. Loss of property, infrastructure and beach width annually cause millions of euros worth of economic damage and loss of valuable coastal habitats, and present significant management issues. At the same time, protection is expensive. During January 2020, a storm named Gloria affected the Mediterranean coast of Spain, provoking severe damage in the coastal strip of the Valencia region, damaging coastal infrastructures and erosion at beaches. The Spanish Government assigned 19.5 million € to beach recovery and coastal infrastructures repairment, of which 4 M€ corresponded to the coastal area of Valencia. [9]

3.4.2 Flooding

Floods are made more likely by the more extreme weather patterns caused by long-term global climate change. Change in land cover—such as removal of vegetation—and climate change increase flood risk.

Extreme floods can be triggered by intense precipitation, longer duration, close repetition of precipitations or a combination of these.

With higher temperatures, we have more energy in the Earth's system. Higher ocean water and air temperatures increase the possibility for evaporation and therefore cloud formation. At higher temperatures, the air can hold more moisture content. This can lead to an increase in precipitation intensity, duration and/or frequency.

Our global temperature in January 2020 was the highest ever on record. The global average temperature is now 1.1°C higher than the beginning of last century.

[9] https://www.lamoncloa.gob.es/serviciosdeprensa/notasprensa/transicion-ecologica/Paginas/2020/170220-gloria.aspx

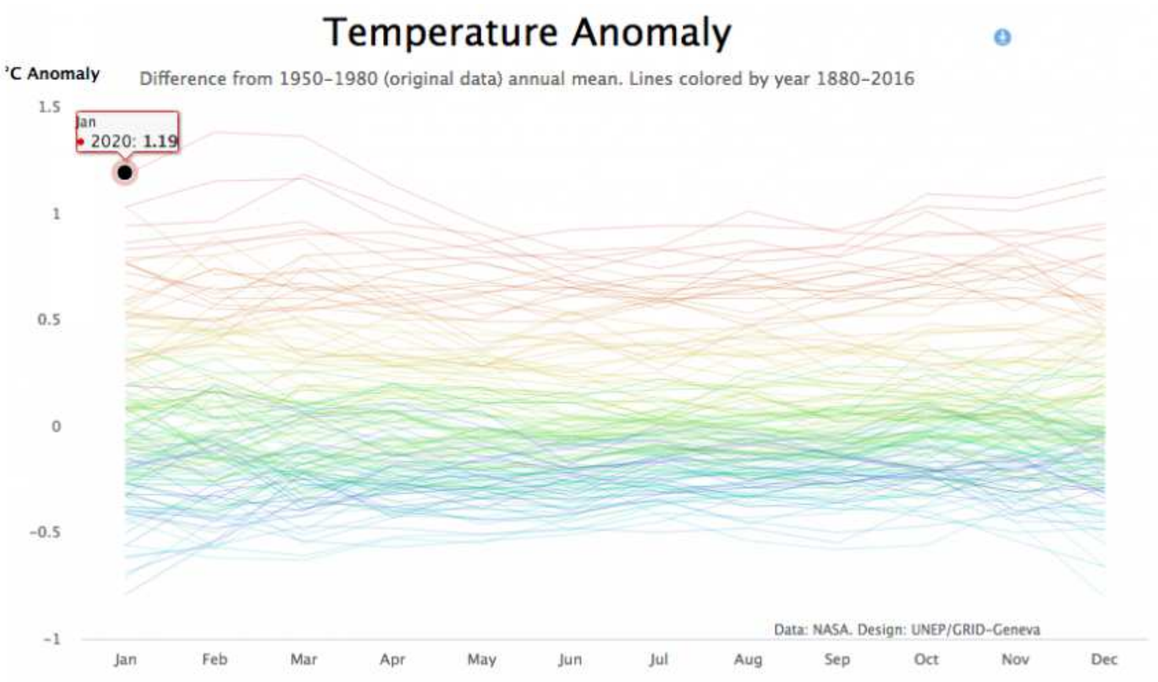


Figure 9 Above average temperatures per month
Source: UNEP World Environment Situation Room: wesr.unep.org

Extreme flooding will continue to be concentrated in SUDOE regions where humans have built on floodplains or low-lying coastal regions. As global warming increases the likelihood for more extreme weather events to occur, risks will expand beyond the high-risk areas known today. More extreme flooding must be expected, and for the towns and cities where flooding has already occured, theirs will no longer be a 'once in a lifetime' risk but now far more frequent.

The terms '**flood damage**', '**flood impact**', '**flood consequences**' and '**flood loss**' are used regularly in the technical literature regarding flood risk management.

The terms '**flood consequences**' and '**flood impacts**' are synonymous, and both refer to the broad effects or results that flooding can have on people, to property and to the environment. These consequences or impacts can be **both positive and negative**, although it is common in the literature to see the terms used in a purely negative sense, which links to the next definition

The terms '**loss**' and '**damage**' are also used synonymously in the literature. Damage is the **negative resul**t of the spatial and temporal impact of an event on societal elements (people, buildings, etc.), societal processes (interruption of production, services, etc.) and the environment.

To understand the damage or losses that floods can cause, it can be useful to categorize them.

Within the literature, there is a broad consensus on the categorization of flood damage.

The first distinction that is commonly made is between tangible and intangible damage. A tangible damage is a damage that is easily capable of being assessed in monetary terms, while intangible is that damage that, in contrast, cannot be so easily specified.

The second common distinction is between direct and indirect damage. Typically, a direct damage is defined as any loss that is caused by the immediate physical contact of flood water with humans, property and the environment. An indirect damage is induced by the direct impacts and may occur – in space or time – outside the flood event. Table 3~~Table 3~~ sums up the classification of flood damages.

Table 3. Classification of flood damages

Measurement			
		Tangible	**Intangible**
Form of damage	Direct	**Physical damage to assets:** **Infrastructure** **Contents** **Buildings** Evacuation and rescue operations Agricultural land Clean-up costs	**Fatalities and injuries** Diseases Historical and cultural losses Loss of ecological and environmental goods Inconvenience
	Indirect	Loss of industrial production Tc disruption Emergency costs Temporary housing of evacuees **Business interruption**	Societal disruption Increased vulnerability of survivors Undermined trust in public authorities Psychological trauma

Source: Adapted from Messner et al. (2007) and Jonkman et al. (2008).

For assessing the vulnerabilities caused by flooding, flood damages have been classified into direct and indirect damage. The firsts occur due to the physical contact of the flood water with people, property or any other element, while the indirect damages are induced by the direct impacts and may even occur outside the flood event. Moreover, these are further classified into tangible and intangible damage, depending on whether or not these losses can be assessed in monetary values. **¡Error! No se encuentra el origen de la referencia.**- Table 3~~Table 3~~ presents a sample of flood damages classified according to the groups that were mention previously. Those considered in the present study are highlighted in bold type.

A considerable part of the literature on flood damages concerns direct tangible damage while other damage types have received much less attention. Within the field of urban drainage and storm water management a consensus has been reached regarding the two essential hydraulic parameters (i.e., water depth and velocity) that have to be taken into account when assessing flood hazard for pedestrians and vehicles.

3.4.3 Water quality

Nowadays, the scientific and research community and most of the countries worldwide, are widely concerned about climate change impacts and threats on environment, global warming, extreme atmospheric episodes and global water availability.

In the in the whole South West Mediterranean area the water use is intensive and the region suffers from frequent droughts, in particular several areas of the Valencian Community and Andalusia. Moreover, during the last decade, droughts have also affected important areas of Portugal, such as the Alentejo or Algarve.

Highly populated cities in the SUDOE space (Valencia, Barcelona, Málaga, etc) are surrounded by an agricultural landscape with a multi-sectoral structure in which irrigated agriculture plays an important role in the consumption of water. The main crops of the SUDOE space are citrus, vegetables and rice in Valencian Community highlighting also dry land agriculture such as the vineyards in the Alentejo and Bordeaux region.

To face drought episodes, in the last years the approaches used in the decision-making process have change from emergency actions to planning measures. In this sense, main River Basin Authorities have developed Special Plans for Situations of Alert and Temporary Drought for the whole river basin and, specifically, municipalities with more than 20.000 inhabitants are required to draft a Drought Management and Emergency Supply Plan.

Additional to severe droughts, the Eastern part of Spain is frequently hit by bouts of extreme rainfall, which cause floods. This phenomenon is called as cut-off low ("DANA" in Spanish.) These episodes frequently need emergency response as they produce the overflooding rivers, cars dragged away in the torrential flow of water, ripping up trees, traffic signs and roofs.

As mentioned before, the water supply system serves areas of high population density where there is significant industrial and economic activity, which requires strengthening the guarantees of both water supply and water supply quality.
The current river basin system includes open channels (Júcar, Segura, Tajo or Duero channels), which represents a special vulnerability both in quantity and quality.
The quality effects may appear due to uncontrolled spills and runoff due to rainfall. The effects related to the quantity are conditioned by the shared use of this channel, as irrigation use greatly hinders the normal maintenance work on the critical infrastructure.
On the other hand, the drinking water treatment system, of a physical-chemical and microbiological nature, is basically adapted to compliance with the current regulations and for the raw water quality conditions observed to date. In this context, the quality of the drinking water supply system is affected by the following parameters:

- the emergence of emerging and complex-type pollutants
- the limitations imposed by the sanitary authorities on the use of chlorinated components
- society's pressure to improve the quality required beyond drinking water in terms of its organoleptic perception

Several studies and researches carried out by the Jucar River Basin Authority (Spain), point out the most significant climate-related effects in what urban water supply concerns. These effects are basically:

- the reduction of water quantity or river flow incomes, observed by the hydrological series of stream-flows and precipitations, since the 80's in the Jucar and Turia upper river basins.
- worsening of water quality produced by increase of pollution sources (nitrates and phosphates) and dilution problems consequence of the decreasing flows;
- increase of the surface water temperature and algae proliferation.

The obligation to ensure the supply of drinking water for the population requires to have redundant contingency plans that allow to solve possible crises in a short period of time. It would be a question of establishing an integral Plan of resources as well as the execution of those basic infrastructures that, together with the actions of demand management, make it possible to incorporate all the resources necessary for human consumption with guarantees of quality and quantity.

3.4.4 Temperature

Extreme heat can increase the risk of other types of disasters. As mentioned before, heat can exacerbate droughts, and hot dry conditions can in turn create wildfire conditions. The heat island effect is most intense during the day, but the slow release of heat from the infrastructure overnight (or an atmospheric heat island) can keep cities much hotter than surrounding areas. Rising temperatures across the country poses a threat to people, ecosystems and the economy.

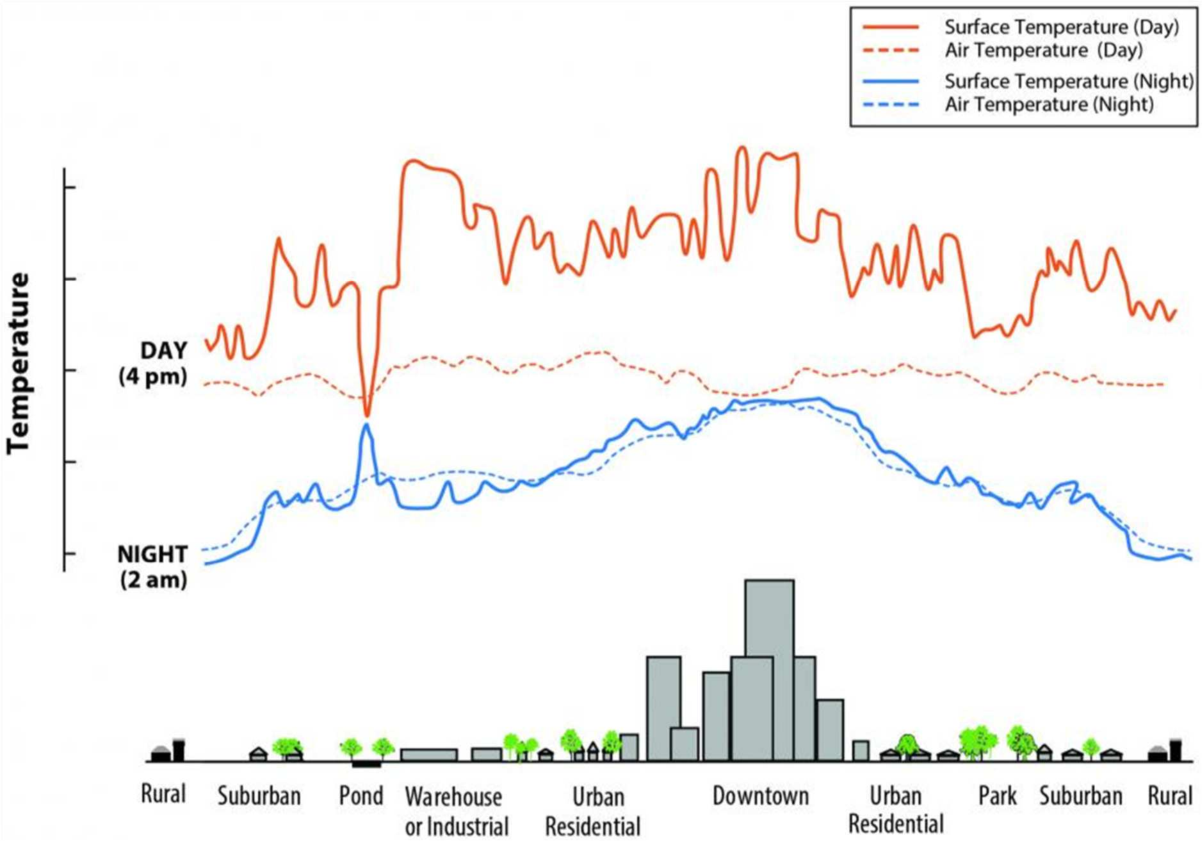


Figure 10 Heat Island Effect Diagram
Source: www.epa.gov

Extreme heat is one of the leading causes of weather-related deaths. Heat stress occurs in humans when the body is unable to cool itself effectively. Normally, the body can cool itself through sweating, but when humidity is high, sweat will not evaporate as quickly, potentially leading to heat stroke. High humidity and elevated night time temperatures are likely key ingredients in causing heat-related illness and mortality. When there's no break from the heat at night, it can cause discomfort and lead to health problems, especially for those who are low income or elderly, if access to cooling is limited.

Hot days are also associated with increases in heat-related illnesses including cardiovascular and respiratory complications, kidney disease, and can be especially harmful to outdoor workers, children, the elderly, and low-income households.

In extreme temperatures, air quality is also affected. Hot and sunny days can increase ozone levels, which in turn affects NOX levels. In addition, greater use of heating and cooling of indoor spaces requires more electricity and, depending on the electricity source, can emit more of other types of pollution, including particulates. These increases in ozone and particulate matter can pose serious risks to people, particularly the same vulnerable groups directly impacted by heat mentioned above.

PESETA project estimated that under a 2°C scenario, the number of heat-related deaths in urban areas could increase 2-3 times. In addition, the ageing of the population will increase the number of people most sensitive to the above mentioned factors.

According to this project, the density of health infrastructure will determine how efficiently increases and peaks in demand can be dealt with in a given region. Forecast results for the effects of these changes on human health are not available on a regional level, however, the Mediterranean regions appear to be the most affected in terms of human health aspects, and will experience a decrease of the quality of life.

One of the indicators measuring the density of health infrastructure is the number of hospital beds in a given area.

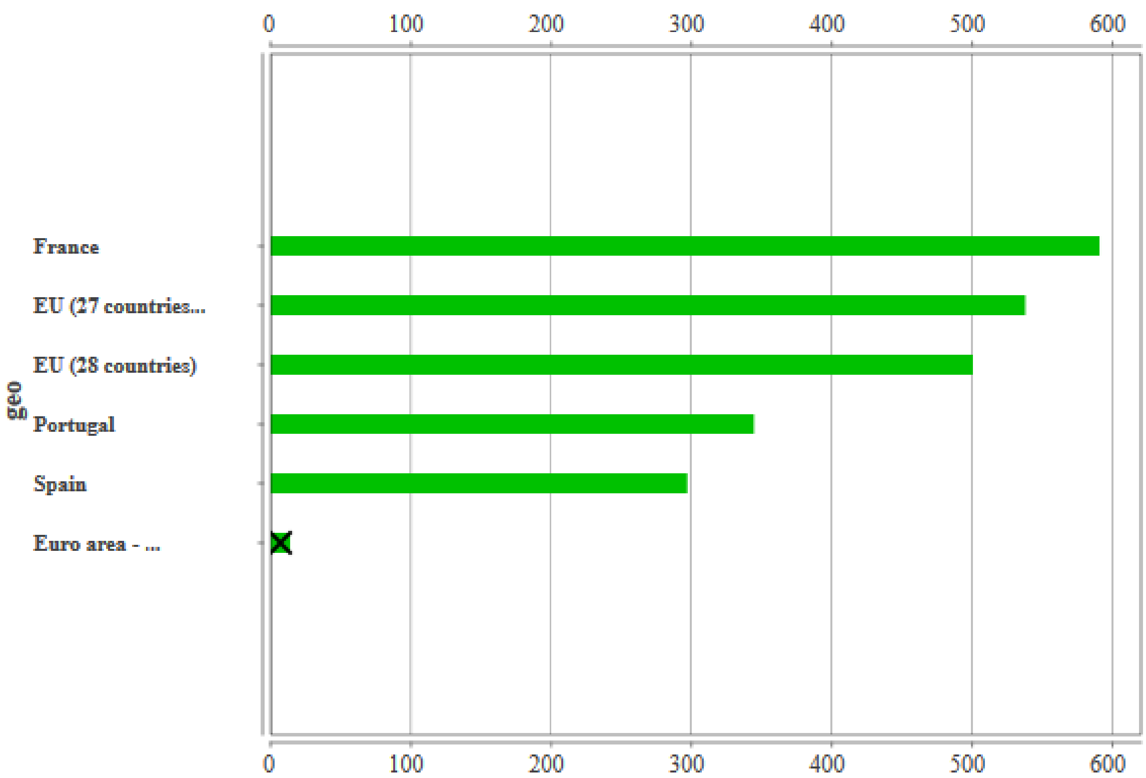


Figure 11 Hospital beds per 100.000 inhabitants
Source: Eurostat, 2018

The ongoing demographic changes in Europe will exacerbate health impacts of climate change. Health infrastructure, particularly hospitals will see a generally increasing demand due to the ageing of the European population. Migration currents, particularly of pensioners, could lead to an over proportional increase in the vulnerable part of the resident population, especially in the Mediterranean regions.

While higher summer temperatures increase electricity demand for cooling, at the same time, it also can lower the ability of transmission line to carry power possibly leading to electricity reliability issues during heat waves. Although warmer winters will reduce the need for heating, modelling suggests that total energy use will increase in a warmer future. In addition, as rivers and lakes warm, their capacity for absorbing waste heat from power plants declines. This can reduce the thermal efficiency of power production, which makes it difficult for power plants to comply with environmental regulations regarding their cooling water.

4 PORTS

4.1 Introduction

The seemingly small variation of only 1.1°C in the average temperature of the Earth's surface from the end of the 19th century until 2011-2016 has already caused changes in the climate of the entire planet (rainfall and winds regime, average and extreme temperatures, etc.) as well as an increase in the frequency, intensity and duration of extreme weather events such as storms, heat waves, floods or droughts, among others.

We will have to coordinate all kinds of measures to reduce emissions, mitigate impacts, adapt and capture CO_2, acting as soon as possible to move away from the most catastrophic scenarios.

Ports are located in coastal zones and because of this, they are susceptible to climate change impacts as obvious as changing wave conditions, sea level rises or storm surges. But because of the location, ports are likely to be affected differently by climate change and associated extreme weather conditions.

Ports are located in coastal areas and, therefore, are likely to suffer significantly some impacts of climate change as evident as changes in the waves, rising sea levels or storm surges. Other consequences of climate change may be less obvious, such as a decline in grains exports due to severe drought, or damage to submerged structures due to changes in water salinity. In any case, the impacts will depend on factors such as the location of the ports, the operations carried out there, the type of infrastructure and existing equipment, etc. and of the magnitude of the associated actions to climate change and extreme events.

The impacts of the climate change may affect both directly (e.g. port infrastructures damaged due to heavy storms) and indirectly (e.g. power cuts due to extreme wind conditions that affect the electricity system).

On one side, ports are key elements in the globalized trading system, therefore climate change impacts on port infrastructures and facilities need to be considered to see how they can accommodate or adapt to these impacts. On the other side, impacts on port operations affect port performance, affecting the level of operability in terms of the amount of uptime, defined as the extent to which it is possible to continue operations such as berthing, mooring or navigating.

In the end, after the analysis of the different climate risks, it is necessary to determine their related consequences, their likelihood to occur and the definition of the operability threshold for the different risks.

Additionally, it is necessary to identify and select the adaptation measures. The adaptation options to mitigate the risk will have to consider, among others, the effective cost of the measure to be implemented, their mitigation level and the time framework.

Because of their critical nature, the ports need to be adapted to current and future climate risks.

Regarding environmental factors referred to climate variables, their variability, and the incidence of extreme events, it should be noted that the time scales of port planning and climate change have reversed their roles. The effects of climate change are already evident and the response of ports to them is not being sufficiently agile. Thus, for example, phenomena that could be expected every 100 years (hurricanes or storms of a certain intensity), are now more frequent and we can expect them every 25 or even every 10 years, and both port infrastructure and superstructure are affected by more intense actions than foreseen when they were designed, and on the other hand they suffer an acceleration of wear and tear with a consequent reduction in their useful life. Ports must change their perception of uncertainty by improving information on climate variables, associated risks and the vulnerability of each of the elements. Long-term downscaling models must be applied in order to know the forecasts of the climate variables that affect each port and the effects that they may produce. Weather variable thresholds must be identified at each facility. With these models it can be calculated, for example, the interval of stop hours for operations, and the operator can decide between improving the equipment to raise the threshold, or assuming the losses for not operating. In general, it allows decisions to be taken on the dimensioning and therefore necessary investments in infrastructure and equipment to maintain the operating conditions of the installations, as well as insurance policies that minimise the economic risks of the activity [10].

For example, some of the potential changes in environmental factors and its associated risks are as follows: a shift towards more extreme environmental conditions is already taking place: the increased intensity and frequency of rainfall can cause flooding because of capacity overload of the drainage systems, damage to warehouses, buildings and or cargo, the failure of inland links to other modes of transport, affecting supply and distribution of goods to and from the ports. Additionally,

[10] *How to deal with the effects of climate change in ports?* N. Monterde. Port Technology Edition 93-2020

extreme precipitations events will affect operations leading to lost work time or even port closures.

High-speed winds can damage buildings, warehouses, cranes and other port equipment as well navigation and communication equipment, can cause delays and stoppages in cargo handling, can make berthing difficult, requiring more tug assistance, or even impossible, and can increase the wave action at waterfront structures and consequently an increase in overtopping rates, hence flooding of berth facilities, and more agitation of the port waters.

High temperatures and heat waves can affect infrastructures and building materials as pavements, steel, asphalt, and others. Also, can affect the structure of equipment, engine cooling and cause power failures. Extreme temperatures can greatly worsen working conditions in berths and on board, and increases the energy demand for buildings, equipment cabins and warehouses cooling, and for reefers.

Fires have an indirect impact on port operations as ports are closed to navigation for allowing waterplanes take water in safe conditions. Periods of high temperatures and low rainfall will produce droughts that will cause water shortages, increased fire risk and poor agricultural commodity production. In some locations, dust storms are also a risk to evaluate.

Other possible effects are those related to wave regimes and storm surges. Changes in the prevailing wave directions can increase internal agitation. Breakwaters could be vulnerable to overtopping in storms combined with sea level rise that could cause flooding of facilities, damages in cargo, infrastructures and equipment.

It can be mentioned effects such as loss of draft in inland ports and navigation channels due to drought, declining water quality due to the presence of invasive organisms caused to changes in water temperature, or variations in water acidity and salinity that can increase corrosion, biodeterioration resulting in higher maintenance costs, among others that is needed to analysed in each particular case.

Given the concentration of populations, assets and services associated with ports - as well as the size and value of built infrastructure - and the crucial role of ports as part of international supply-chains, climate change impacts on ports and their land-based access points, linking the maritime interface with the hinterland, may have serious broader implications; developing effective adaptation response measures is therefore of strategic economic importance (UNCTAD, 2018). So, in the market and logistic context, the degree of uncertainty in the medium term is very high. Measures taken with regards to the decarbonization of the economy can change production and consumption patterns. The risk of disruptions in transportation and storage due to extreme climate events and the more than possible internalization of the costs of transport emissions will bring the centres of production closer to those of consumption, in a combination process of deglobalization and greening of the economy. Global warming will drive the relocation of agricultural production to moderate climate latitudes to maintain productivity, which would require new ports, and will reduce of productivity in existing areas, consequently reduction of traffic in linked ports. Oil and coal shipping can be reduced to historic lows. Ports must install LNG and other alternative fuels bunkering infrastructures, must move to cold ironing and renewable energy sources, being as independent of general grids as possible in order to guarantee supply. It is also expected an increased pressure on the coastline due to rising average sea levels, changing the need for space for retreating populations, and for ports and logistics facilities. Finally, in each location there are local effects to be studied.

A good understanding of the relevant risks and vulnerabilities based on accurate information, including climate and socio-economic data at the local level, is a pre-requisite for informed decision making and well-designed and effective adaptation response measures that enhance the robustness of systems, structures and processes and minimize the adverse effects of climatic factors (UNCTAD, 2018).

In this sense, ECCLIPSE project focuses on the direct effects of climate change on port infrastructures and operations. The situation of the ports of Valencia, Aveiro and Bordeaux will be analysed in depth as case studies.

4.2 Maritime transport and port operations

Ports are key nodes of the international transport network and play a key role in the globalized transport. Seaborne trade is responsible of nearly 80% of the total world merchandise trade in tonnage (UNCTAD 2017), which explains the relevance of ports in the global trade. Port competitiveness is closely related to the operability levels so that the aim is to maximize the port uptime for continuous operations (e.g. navigation, pilot, berthing, mooring, etc.) avoiding downtimes causing loss in productivity. In this sense, climate change can heavily influence these operations, making necessary to secure the operability of the seaports under the climate changing conditions to maintain the current competitiveness levels. Variations in the frequency and intensity of local the climate hazards such as storm surges, fog or wind speed due to climate change can modify ports performance. Because of this, becomes necessary to understand the potential local-scale climate change impacts to explore suitable adaptation and mitigation strategies.

To identify these climate hazards, a seaport questionnaire was developed by the UNCTAD in consultation with experts and port industry stakeholders. The questionnaire was widely circulated to the port industry, thanks to the assistance in the distribution of some industry associations such as the IAPH and the American Association of Port Authorities (AAPA).

The respondent ports were located in 29 countries representing all regions, even though the majority of them were located in Europe (36%), Asia (30%) and North

America, with only a few responses received from Oceania (7%), Africa (5%) and South America (2%) (Asriotis et al. 2017). Besides, the survey count with the participation of all kind of stakeholders of the maritime and port industry such as port authorities, terminal operators, private ports, etc. Following Figure 12~~Figure 12~~ and Figure 13~~Figure 13~~ show some of the key responses related to climate hazards and impacts on the port industry.

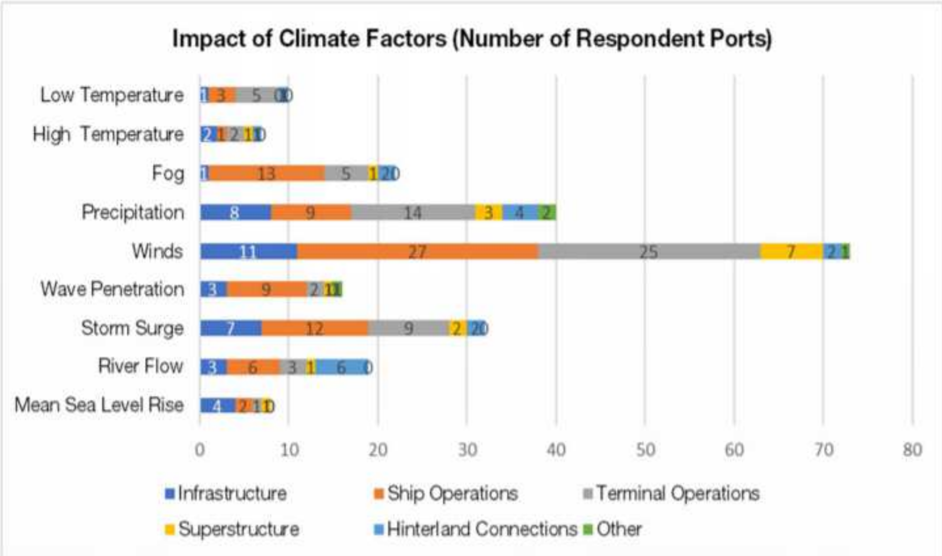


Figure 12 Impact of climate factors on port infrastructure, operations and services (Number of respondent ports)
Source: UNCTAD Research Paper No. 18 (Asriotis et al. 2017)

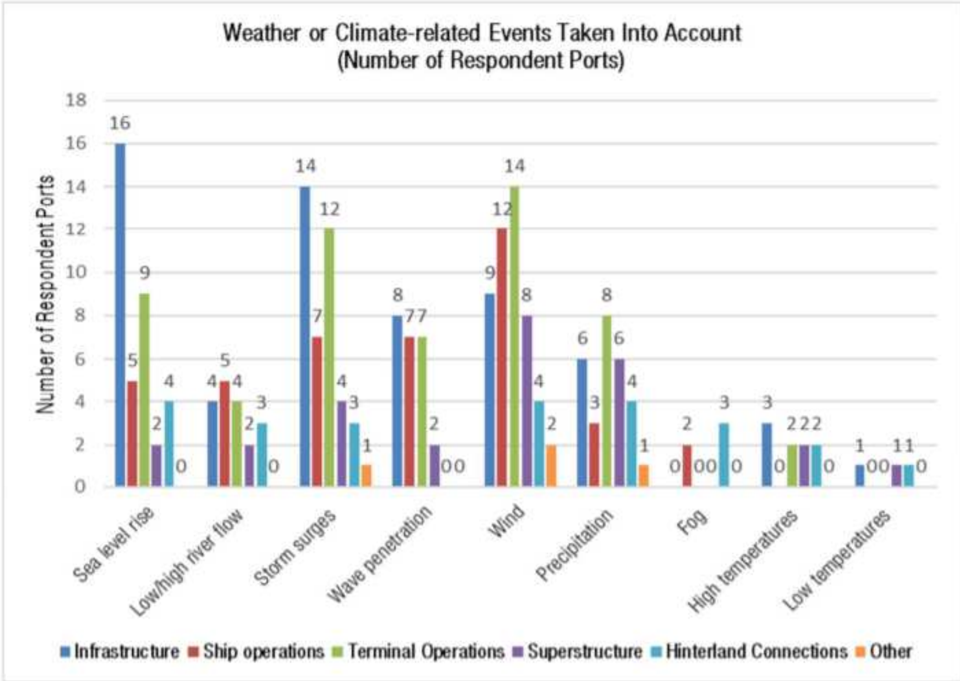


Figure 13 Respondent vulnerability/impact assessments (number) that have considered the impacts of different climate stressors on port components
Source: UNCTAD Research Paper No. 18 (Asriotis et al. 2017)

Finally, Puertos del Estado (2016), which is the public managing body of the Spanish port system elaborated a survey about the main impacts associated with climate events that currently affect port operations. The survey was distributed among the 27 port authorities that comprises the Spanish port system and the following Figure 14~~Figure 14~~ shows the main results:

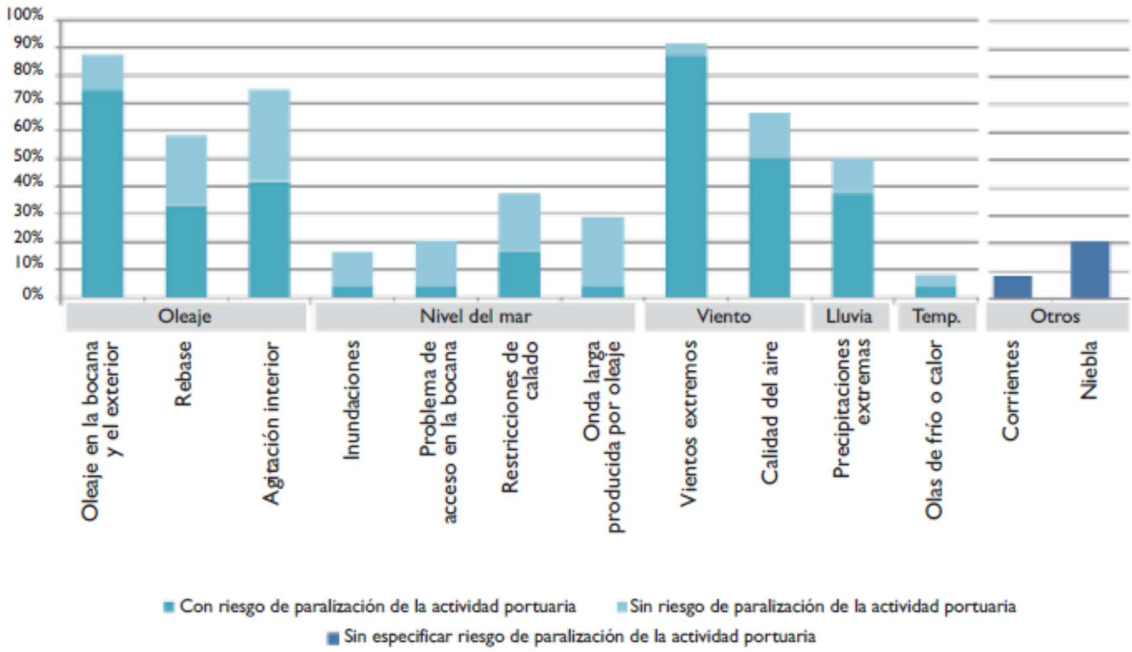


Figure 14 Percentage of Port Authorities facing problems related to the different climate hazards.
Source: Puertos del Estado (2016)

As can be seen from the different questionnaires carried out by different sources, the main climate risks for port operative are:

1. Sea Level Rise
2. Storm surges and waves in the port access and outside the port facilities
3. Inner agitation inside the port
4. Extreme wind conditions

Summing up, it seems reasonable to conclude that the increase of the sea level and the modification of the wave patterns may affect port operations increasing the number of days in which the agitation inside port facilities and breakwater overtopping events could reduce the operative days.

4.3 Port infrastructures

The design and construction of the maritime infrastructures is determined by the maritime weather conditions of the area. In this sense, for their design becomes essential to know the main parameters that affect the infrastructure, which are wave height, wind, sea currents and sea level (including tides). For instance, breakwater design and construction is mainly based on the wave height. The dock is designed for a return period (e.g. 300 years) and its associated extreme wave height. Thus, changes in the climate conditions that affect this variable (e.g. increase of the sea level or heavier storms surges that modify the wave heights) affect directly the lifespan of the breakwater and the rest of infrastructures protected by it. In the case of Spain, maritime infrastructures are based on the ROM 0.3-91 (MOPT 1992), which defines the extreme and medium conditions measured by the buoys network of "*Puertos del Estado*", the public body in charge of the management of the Spanish port system.

Table 4~~Table 4~~ summarizes the different climate-related parameters that affect the different kind of infrastructures that can be found in a port.

Table 4. Climate-related parameters affecting port infrastructures

Element type	Environmental agent						
	waves	sea level	wind	currents	phreatic level	rainfall	extreme temperature
Dredging	x			x			
Vertical Breakwater	x	x	x				
Rubble-mound breakwater	x	x			x		
Gravity Quaywall		x	x		x		
Sheet pile Quaywall		x	x		x		
piled Quaywall		x	x				
Storage facility		x			x	x	
Road/transport facility					x	x	x

Source: Own elaboration

4.4 Identification of cascading effects

Concatenated effects are expected from some impacts on the infrastructures and on the operational level. For instance, intense rainfall reduces performance level of yard operations in port terminals but also can produce power shortcuts, which has important consequences due to the number of services that depend on electric power (e.g. communications, security, etc.).

Ports are nodes of the global logistics chains and they are located, in most of the cases, in highly populated areas with good infrastructure connections. Consequently, cascading effects are not limited to the port area and the impacts on ports have affections to other linked transport modes such as railway and road transport. Thus, cascade effects move through the entire supply chain of goods and, in case of passengers' vessels, affecting passengers' mobility.

Finally, effects between urban and port areas also need to be taken into account. For example, a possible insufficient urban drainage could cause floods in electric substations and therefore consequent impacts on the inland port operations such as planning, communications, crane operations, monitoring, etc. Other example could be the collapse of the city traffic management system due to climate hazard that could affect the road transport, which usually is the most important transport mode to deliver/pick-up goods to/from the port.

These two examples highlight the importance of the understanding of climate hazards and the interdependencies between them and the ports and urban environments, making essential the analysis of the cascading effects.

Following Table shows some indicative risks associated to climate change that may affect ports based on the Climate change adaptation guidelines for ports and other sources (Jaroszweski 2010, Scott *et al.* 2013). Moreover, in order to better understand the impacts, the climate variables and risks have been differentiated based on the impact on infrastructures and/or ports operations.

Table 5. Most relevant climate hazards for ports

Climate variable	Climate risk hazard	Level

Rainfall intensity	• Extreme flooding, poor visibility, difficult cargo handling
	• Damage to buildings and cargo (floor leaking and water damage)
	• Soil damage due to drainage overload:
	  • Foundation damages
	  • Infrastructure damage (roads, railways, etc.)
		Operational level
		Infrastructure level
		Infrastructure level

Heat wave	• Extreme temperatures that require to stop operations • Higher energy consumption (refrigerated cargo) • Reduction in operational performance due to higher temperatures • Damages and deterioration of pavements and other infrastructures (thermal stress and deformations)	Operational level Operational level Operational level Infrastructure level
Storm surge	• Increased intensity and frequency of the storm surge • Changes in mean offshore wave conditions • Beach erosion • Higher waves:	Infrastructure and operational level Infrastructure level Infrastructure level Operational level

	• Increased agitation inside the port dock • Higher wave height (breakwater design parameter) • Damages in breakwaters and docks	Infrastructure level Infrastructure level

High speed winds	• Increased intensity and frequency of the high speed winds
	• Beach and dunes erosion
	• Changes in mean offshore wave conditions
	• Higher speed winds:
	  • Higher wind speed that required to stop crane operations
	  • Difficult cargo handling
	  • Difficult port operations (navigation, berthing, piloting, mooring, etc.)
	  • Higher wind speed (breakwater design parameter)
	  • Damage to buildings and cargo
		Infrastructure and operational level
		Infrastructure level
		Infrastructure level
		Operational level
		Operational level
		Operational level
		Infrastructure level
		Infrastructure level

Fog	• Increased intensity and frequency of the foggy days that stop port operations	Operational level

Sea level rise	• Higher waves due to the increase of the sea level:
	  • Modification of the design parameters (wave height)
	  • Changes in mean offshore wave conditions
	  • Dock flooding
		Infrastructure level
		Infrastructure level
		Operational level

Drought	• Navigation problems on inland waterways	Operational level

Source: UNCTAD Research Paper No. 18 (Asriotis et al., 2017)

Regarding ports, the key feature to be preserved is competitiveness, which can diminish by infrastructure and operational issues due to extreme climate events. A total of six meteorological variables were identified according to the port susceptibility to climate: sea level (mean and extreme storm surges), wave height, wind speed, fog, precipitation (extreme rainfall and droughts) and temperature (heat waves).

Besides this, the UNCTAD (Asriotis *et al.* 2017) identified the major climate factors impacting ports

Table 6. Major climate factors impacting ports

Climatic Factor	Impacts on open sea, estuarine and inland waterway ports
Sea level (mean and extreme)	
(i) Mean sea level changes; (ii) increased destructiveness of storm surges/waves; (iii) changes in the wave energy and direction	Damages in port infrastructure/cargo from incremental and/or catastrophic inundation and wave regime changes; higher port construction/maintenance costs; potential modulation of tides causing sedimentation/dredging in port/navigation channels and operational time table changes; effects on key transit points; increased risks for coastal road/railway links; relocation of people/businesses; insurance issues.
Temperature and evapotranspiration	
i) Higher mean temperatures; (ii) heat waves and droughts; (iii) increased spatio-temporal variability in temperature extremes	Damage to infrastructure/equipment/cargo and asset lifetime reduction; increases in the staff health risk; higher energy consumption for cooling terminals and cargo; restrictions for inland navigation that may affect estuarine port competitiveness (e.g. port of Rotterdam); reductions in snow/ice removal costs; extension of the construction season; changes in transport demand

Precipitation and fog	
(i) Changes in the mean and intensity or frequency of extremes (floods and droughts)	Land infrastructure inundation; damage to cargo/equipment; navigation restrictions in inland waterways; network inundation and vital node damage (e.g. bridges); problems in port equipment operations (e.g. cranes); changes in demand.
(ii) Increases in fog intensity/duration	Impact on ship and terminal operations (reduced visibility)
Wind	
Extreme harbour winds	Problems in seaport navigation and berthing; operational disruptions due to inability to lead/unload

5 STUDY CASES

5.1 Port of Aveiro

Port of Aveiro is located in an inland lagoon called the Ria de Aveiro (Aveiro Estuary). The Estuary came about due to the retreating sea, leading to the appearance of coastal strips and the subsequent formation of a lagoon that is one of the most important and valuable hydrographical accidents that occurred on the Portuguese coast.

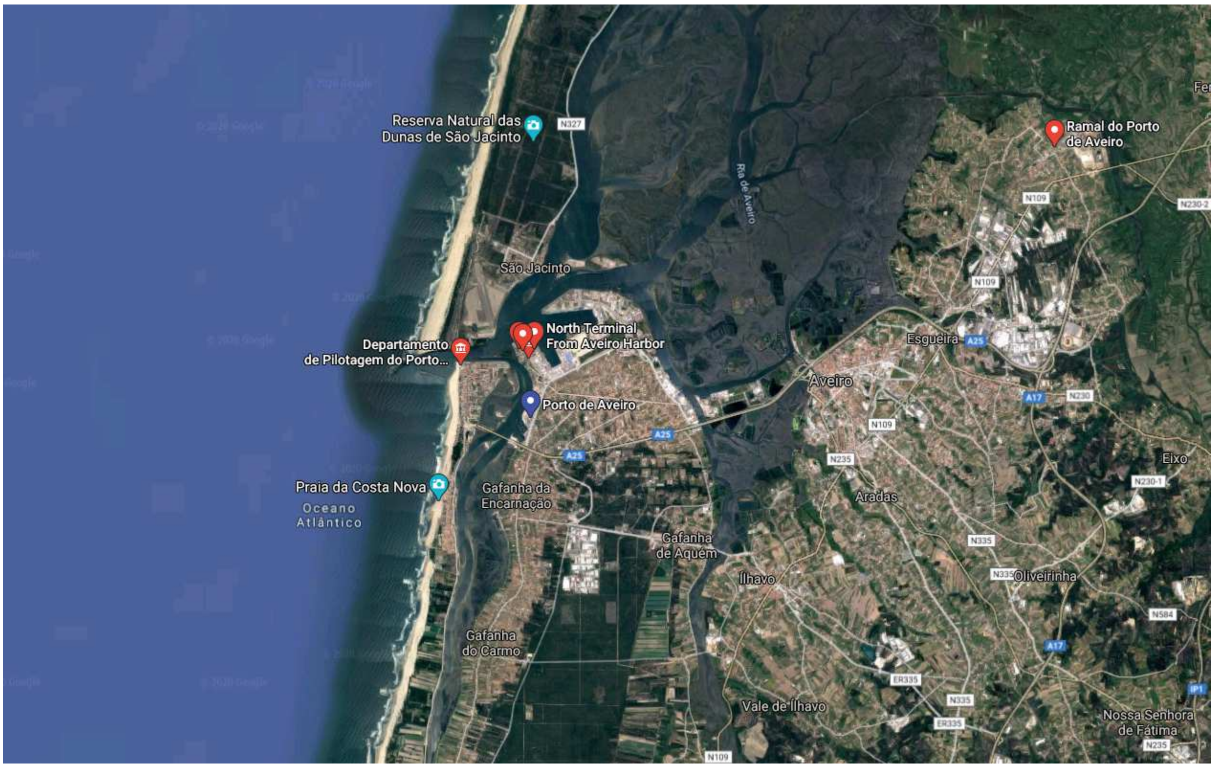


Figure 15. Port, city and lagoon (Estuary) of Aveiro
Source: Google Maps

Maritime access to Aveiro harbour is stabilised to the depth of around -12 m (Chart Datum). In view of the increased demand for larger vessels in the Port of Aveiro, the port is promoting the elaboration of a study to improve the port's navigability conditions, focusing on the reinforcement of the security conditions in its access, as well as greater reliability in its operation. The main navigation channel is 9 km long, running from the entrance of the Harbour to close by the city of Aveiro.

Port of Aveiro is served by a set of non-congested motorways (A1, A29 and A25) which connect the region to the main cities of Portugal and Spain. These accesses make Port of Aveiro an important node of the development of Short-Sea Shipping.

To boost its trading relations with Spain, Port of Aveiro is integrated into the Trans-European A-62/AP1 corridor of the logistical network of Castilla y Léon.

In addition, the railway connection of Port of Aveiro links the port to the Northern line (main railway line in Portugal) and to Spain via Beira Alta line.

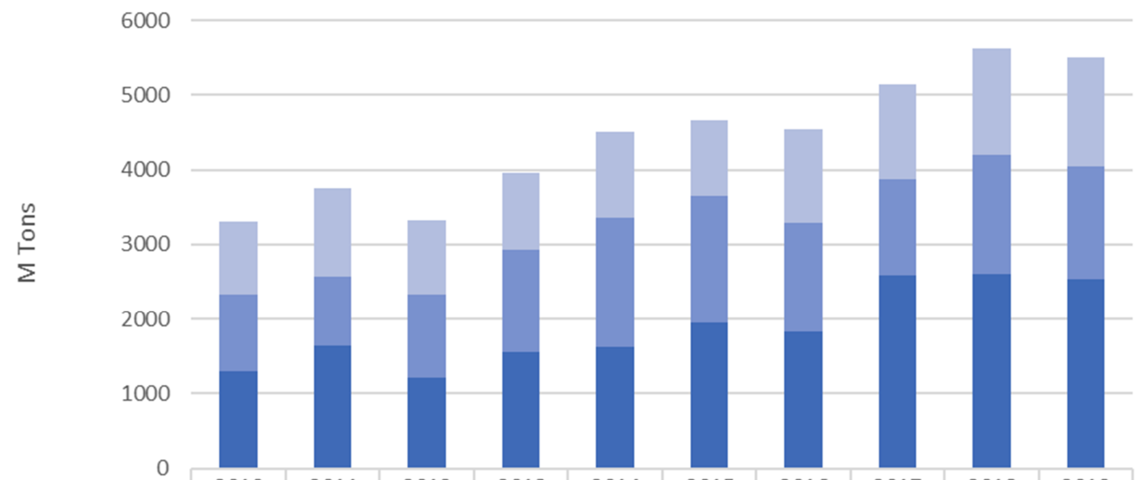
Aveiro is a multifunctional port, playing a major role in the service of the various sectors of its hinterland industry, such as the ceramic, chemical, metalworking, wood and wood derivatives industries, as well as the agri-food and construction sectors.

With an annual throughput of around 5.5 million tonnes in 2019, the port has the following facilities:

- North Terminal: It is the main multipurpose terminal in the port, offering an installed capacity of 4.5 million tonnes/year. Aimed at handling general cargo and solid bulk, it has a mooring berth of 1,150 m and allows the entrance of vessels with an average draft between 9 and 9.75 m (Chartum Datum).
- South Terminal: it is another multipurpose terminal. This terminal handle mainly general and bulk cargo. With 400 m of quays and prepared to dock vessels with an average draft of 5.5 m (Chartum Datum), this terminal has the capacity for both covered and uncovered storage
- Container and Roll-On/Roll-Off Terminal: this terminal is prepared to receive container and Ro-Ro cargo. It has 450 m of quays and a 200 m Ro-Ro ramp. Its characteristics enable it to dock vessels with an average draft of 9,75 m (Chartum Datum). It has both covered and uncovered storage capacity, as well as embankments prepared to receive new logistics units.
- Solid Bulk Terminal: This terminal has 750 metres of quays and 15 ha. It has available area for investment in logistics units measuring around 4.5 ha.
- Liquid Bulk Terminal: It has 6 quay bridges and is prepared to dock vessels between 100 and 170 m in length and 7.0 and 9.25 m in average draft. It is served by excellent railway connections and has areas for the installation of logistics units on the 1st or 2nd line of the seafront, with the port areas being conceded according to the needs of the players. The facilities are run by private companies who are specialised in the transport of chemical products, petrol products and biodiesel. This terminal serves one of the main centres of the National Chemical Industry, located near the Port of Aveiro.
- Coastal Fishing Port: This area is dedicated to unloading, storage and commercialisation of the fish catch. The fish stalls and ice factory are yielded to Docapesca – Portos e Lotas - S.A.
- High Sea Fishing: this terminal serves the high-sea fishing boats and fish processing industries installed at Gafanha da Nazaré, specially dedicated to the cod fish processing. It has 18 quay-bridges at medium depths of approximately -5 metres (Chartum Datum) and a weighing bridge with capacity of up to 60 tonnes.
- ZALI - Logistical and Industrial Activities Zone of Aveiro: this 73 ha area has excellent road accessibilities with a seafront of 1000 meters of quays, is located in an area adjacent to the Container and Ro-Ro Terminal. The ZALI offers competitive maritime and road-rail connections to international markets, including the possibility for economic operators to use a private quay. Today, it offers lots of land with 28 ha, and it is expected that in 2022 its capacity will be increased by another 45 ha.

All types of traffic in the port are growing, but solid bulk traffic is growing faster. The total traffic has gone from 3.3 million tons in 2010 to 5.5 million in 2019. In 2010 solid bulks accounted for 34% of the total, liquid bulks for 30% and general cargo for 36%. In 2019, these percentages are 46%, 26% and 28% respectively. In addition, imports are growing faster, going from being an import-export balanced traffic, to have 72% of imports in 2019.

Figure 16. Port of Aveiro Map
Source: web page of Port of Aveiro (www.portodeaveiro.pt)



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
General cargo	978	1181	991	1032	1147	1013	1245	1278	1427	1447
Liquid bulk	1034	936	1122	1372	1732	1686	1457	1286	1601	1512
Solid bulk	1299	1637	1207	1559	1632	1956	1838	2586	2595	2536

Figure 17. Port movement by type of cargo
Source: web page of Port of Aveiro (www.portodeaveiro.pt)

Challenges:

The port is subject to the Atlantic climate in general, but due to its location in the Ria de Aveiro, *a priori* it is considered necessary to analyse the effects of climate change on the estuary system, considering as main factors of analysis currents, sea level, sea waves and sediment transport.

5.2 Port of Bordeaux

The Atlantic Port of Bordeaux is in the Gironde Estuary, a centuries-old waterway, and the location of major environmental issues such as marine biodiversity, wetlands and water quality.

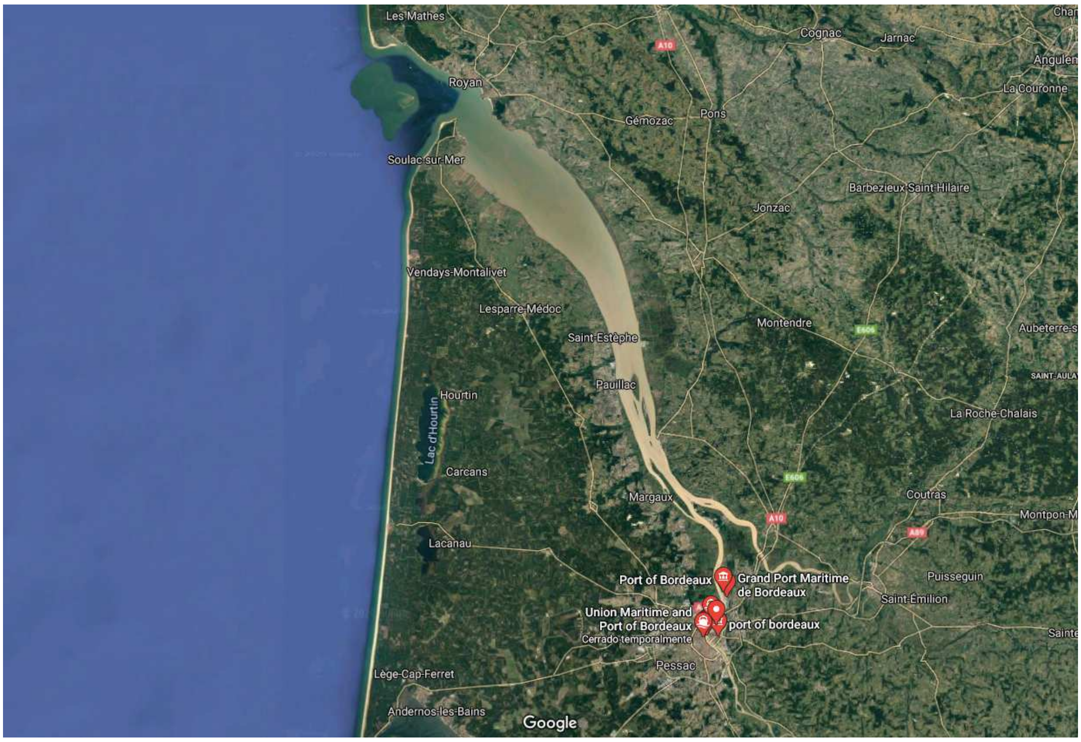


Figure 18. Port and city of Bourdeaux and la Gironde Estuary
Source: Google Maps

The Port of Bordeaux is a key asset to the Nouvelle-Aquitaine region's development and international status, providing new market opportunities for the regional economy (in particular in agrifood, wine and spirits, wood and paper industries, aerospace, defence, advanced materials - including composite and ceramics -, green chemistry and eco-processes, renewable energy and more),

It reinforces the appeal of the Bordeaux area, an economic hub midway between Paris and Madrid, and Western Europe's gateway to the Atlantic.

The port is positioned at the heart of a dense and diversified network of transportation options by land and sea. As a hub of the European transport network, it boasts an excellent road system (with 5 major motorways A89, A62, A63, A65, A10), rail system (including the high speed rail line to Paris) air transport, (Bordeaux Merignac is France's largest regional airport) and maritime connections with more than 300 ports.

The port hast seven specialised terminals which span the length of the Gironde Estuary. There are more than 100 km between Bordeaux city centre and Le Verdon:

- Le Verdon terminal is a deepwater port (12.5 metres draft) with a large surface available at quayside and a 12,000m² hangar. It is specialising in containers, but also handles heavy lift cargo. There is an anchoring point for large cruise ships. The terminal has 3 quayside berths, two container gantries and a roll-on/roll-off ramp. A rail network directly links the port terminal to the Bordeaux metro area. Le Verdon boasts the South West Europe Container Terminal (TCSO), an upgraded terminal that offers simplified customs procedures with tax advantages. The annual traffic at the terminal is more than 200,000 tonnes per year.
- Pauillac Terminal is on the left bank. It has several mooring points for oil tankers and is the principal regional logistical centre for Airbus components that arrive by sea are then transferred to specially-fitted barges which take them on to Langon. The convoys continue to Toulouse by road. Nearly 710,000 tonnes of cargo are shipped each year from the Pauillac site.
- Blaye terminal: With a circulation of close to 300,000 tons of cargo per year, the site at Blaye is dedicated to the trade of bulk liquids, but also cereal exports.
- Ambès Terminal: located at the confluence of the Dordogne and the Garonne, the terminal is equipped for the transit and storage of hydrocarbons and chemical products. Nearly 4 million tons per year (half of the port's trade) pass through the terminal (petrol, diesel oil, domestic fuel, fuel oils, crude oils, ...).
- Grattequina Terminal: located close to central Bordeaux, this terminal has a high-capacity wharf for handling construction materials (aggregates). Grattequina can also handle oversized cargo. The terminal has a 6-hectare site pre-equipped to accommodate logistics and industrial facilities.
- Bassens Terminal is located on the right bank. This terminal handles most of the goods which pass through the port. With over 3 km of quaysides, the site's activities are varied: recycling, cereals, oilseeds, industrial bulk, containers, forest products, heavy parcels, cruises..., which accounts for over a third of the port's total traffic (more than 3.2 million tons per year). The Bassens site has a direct rail link.
- Bordeaux Terminal: Called the Port of the Moon, the terminal is totally reserved for cruise ships, making the port of Bordeaux one of the few European ports of call allowing cruise ships up to 255 m to dock in the very centre of a historic city on UNESCO's World Heritage list.

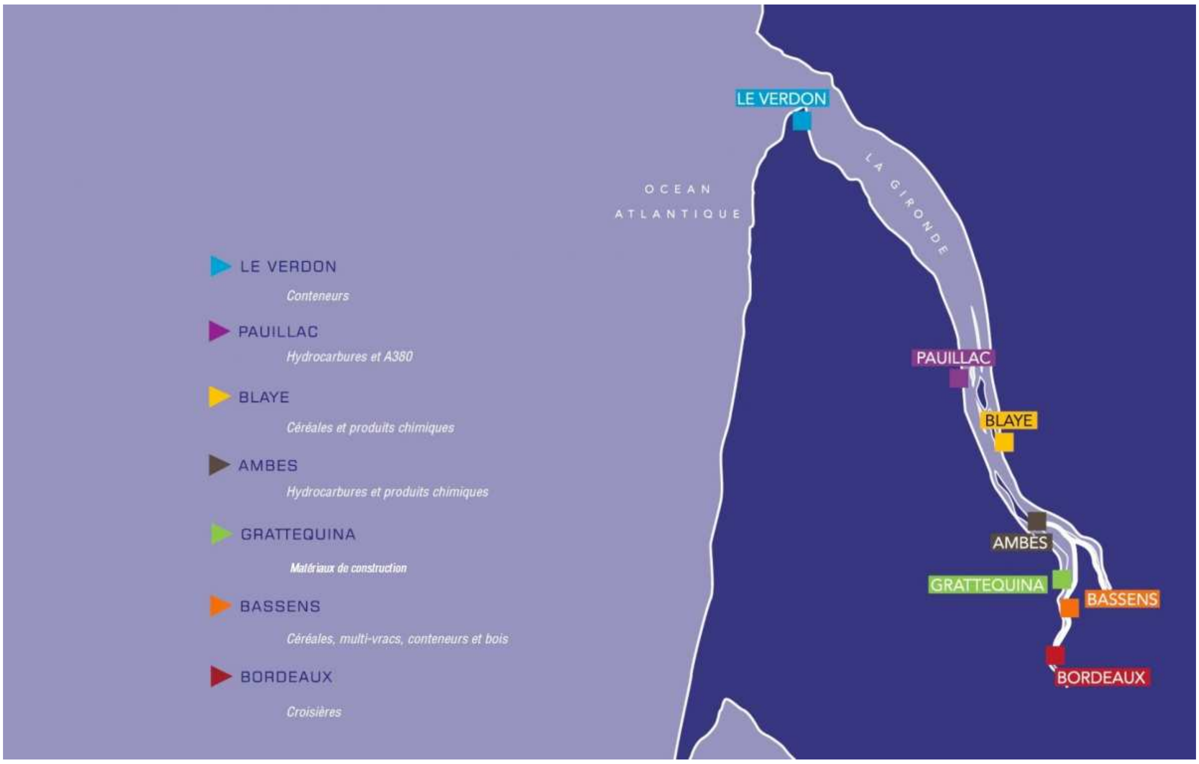
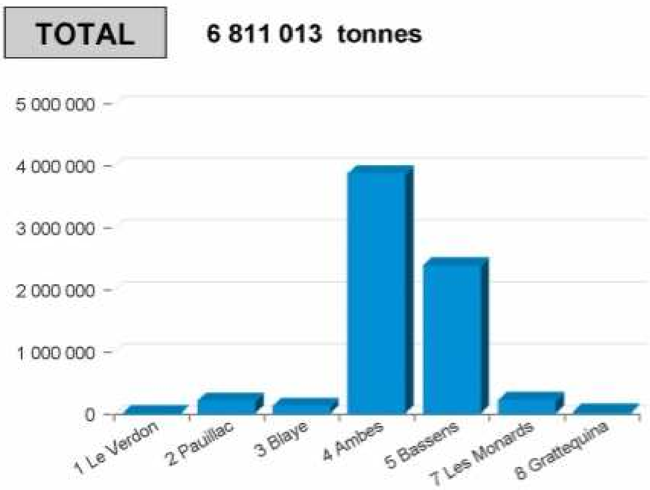


Figure 19. Port of Bourdeaux Map
Source: web page of Grand Port Maritime de Bordeaux

The total throughput in 2019 at the port was 6 811 013 tons, with a slight decrease of 3.6% from the previous year. The main terminal was Ambes with almost 3.87million tons, handled more than half of the port's traffic. For its part, Bessens operated 2.38 million tons. Depending on the volume handled, oil products, with almost 3.8 million tons, 56.7%, are the main product, followed by cereals and oil seeds with almost 980 thousand tons (14.3%), and fertilizers with just over 450 thousand tons (6.7%).



Zones portuaires	Total
1 Le Verdon	20
2 Pauillac	203 358
3 Blaye	117 820
4 Ambes	3 866 869
5 Bassens	2 384 688
7 Les Monards	213 725
8 Grattequina	24 533
TOTAL	6 811 013

Figure 20. Throughput per terminal, 2019
Source: web page of Bourdeaux Port

Catégories	Tonnage
01 Hydrocarbures	3 793 652
02 Céréales et graines oléagineuses	976 608
03 Tourteaux et huiles	269 615
04 Engrais	453 917
05 Charbon et coke de pétrole	119 663
06 Conteneurs	320 053
07 Granulats	238 258
08 Autres	639 247
TOTAL	6 811 013

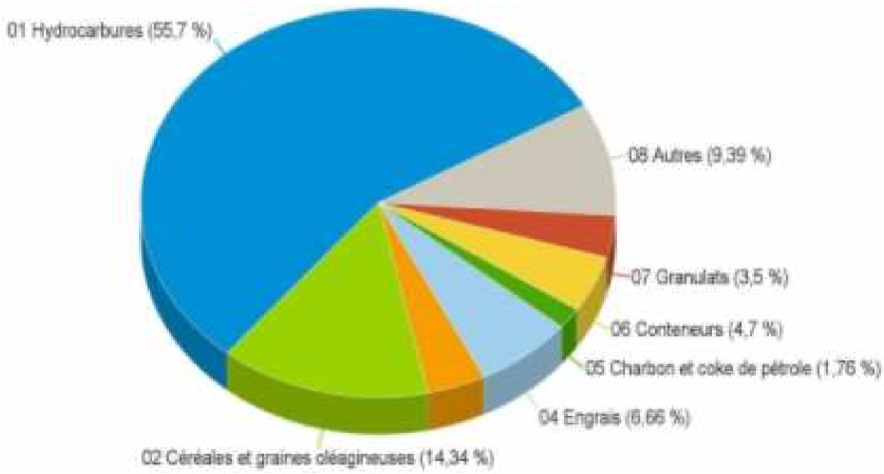


Figure 21. Port movement by type of cargo, 2017
Source: web page of Port of Bourdeaux

<u>Challenges:</u>

The port is subject to the Atlantic climate in general, with the particularities of the Gulf of Gascogne. Due to its interior location in the Gironde Estuary it is considered necessary to analyse how the climate change affects the estuary system, specifically on the parameters associated with the phenomena of submergence, lower upstream flow, heat waves and salinity.

5.3 Port of Valencia

Port of Valencia is located in the south-western Mediterranean, surrounded by the city of Valencia and just north of the Turia River, whose course was diverted due to the recurrent flooding the city suffered from convective rain phenomena.

Figure 22. Port and City of Valencia, old and new Turia's riverbeds
Source: topturisme.com

Valenciaport is the first and last port of call for regular shipping lines operating in the Western Mediterranean, due its excellent location in relation to the Suez-Gibraltar axis – the main route for interoceanic shipping lines. This gives the port high capacity for concentrating and distributing traffic in the Western Mediterranean.

Valenciaport's direct area of influence has a radius of 350km – an area that generates 51% of Spain's GDP and includes half of Spain's entire working population.

Valenciaport is located in the heart of the Valencia Region, and has excellent road and rail connections to the centre of Spain, making it the maritime entrance for goods destined to Madrid, and a logistic platform for the entire Iberian Peninsula. As Western Mediterranean hub, Valenciaport distributes goods over a radius of 2,000km, both in southern EU countries and in North Africa through regular interoceanic and regional connections with other major world ports: over 100 regular lines and 1 000 ports throughout the world.

The Port of Valencia is directly linked to national and international road and rail networks. By road is connected to the national road network via the V-30 (bypass around the city of Valencia) that links up directly to the A-7 motorway, which in turn is directly connected to the other road links in the port's hinterland:

- The V-21 trunk road to the north (Valencia-Sagunto).
- The V-31 trunk road to the south (Valencia-Silla).
- The north-south corridor which includes the A-38 (Valencia-Cartagena) and the A-7 (Barcelona-Algeciras) motorways.
- The East-West corridor centred on the A-3 toll-free motorway (Madrid-Valencia) which connects to the A-43 motorway to Lisbon, on the stretch near Atalaya.
- The section of the A-7 motorway near Sagunto links up to the A-23 (Sagunto-Somport) toll-free motorway which connects the region with Aragon, Castile-Leon and the rest of the north of Spain. The A-7 near Xativa also links up to the A-35, which accesses the south of Castile La Mancha.

The railway connections from Valencia ensure access to any manufacturing area on the Iberian Peninsula and Europe. The rail links from the Port of Valencia are as follows:

- Valencia – Barcelona – Port Bou
- Valencia – Zaragoza – Basque Country
- Valencia – Cuenca – Madrid
- Valencia – Albacete – Madrid. From Madrid, there are links to Extremadura and Portugal, as well as the north and northwest areas of Spain.
- Valencia – La Encina – Alicante, which provides connections to other destinations from Alcazar de San Juan (Andalusia), Alicante (Murcia), Madrid (north and northeast Spain, Extremadura).

Port spaces are structured into zones that have the necessary features for hosting and handling each type of traffic. Some zones are articulated in specialised terminals. Other facilities are characterised by being multi-purpose for diverse types of traffic. The cargo and passengers' facilities at the port as are follows:

CONTAINER TERMINALS:

- CSP Iberian Valencia Terminal: 1,830 m quay long with a maximum depth of 16 m and a total surface of 1,124,000 m^2.
- MSC Terminal Valencia: 770 m quay long with a maximum depth of 16 m and a total surface of 382,427 m^2.
- APM Terminals Valencia: 1,660 m quay long with a maximum depth of 16 m and a total surface of 502,000 m^2.

LIQUID BULKS (OIL PRODUCTS):

- TEPSA Terminal: This is a terminal for oil and chemical products. It has 299 m quay long with a maximum depth of 16 m and a total surface of 59,800 m^2.
- Galp Energía España: This is a terminal for oil and chemical products. It has 299 m quay long with a maximum depth of 16 m and a total surface of 62,800 m^2.

LIQUID BULKS (ASPHALT, VEGETAL OILS AND MOLASSES):

- Productos Asfáticos: This terminal is mainly dedicated to asphalt products. The quay is 153 m long with a maximum draught of 9 meters and a 5,500 m^2.
- Teva- Tank: The terminal is mainly dedicated to other liquid bulks. The quay is 376 m long with a maximum draught of 9 meters and 3,900 m^2.

SOLID BULKS (GRAINS AND CEMENT):

- Holcim España: This terminal is mainly dedicated to cement. The quay is 598 m long with a maximum draught of 16 meters and 3,000 m^2.
- Cemex España: The terminal is mainly dedicated to cement. The quay is 183 with a maximum draught of 14 meters and 5,100 m^2.
- Temagra: This terminal is dedicated to grains. The quay is 595 with a maximum draught of 14 meters and 64,342 m^2.

RO-RO CARGO

- Dique del Este Terminal: The terminal is operated by Valencia Terminal Europa and Ford. It has 1,250 m quay long with a maximum draught of 16 meters and 311,654 m^2.
- Xità Terminal: The terminal is operated by Ford and has 100,000 m^2.

FERRIES AND CRUISES (PASSENGERS)

- Transmediterranea Terminal: This terminal is for passengers and cruises. The quay is 520 m long with a maximum depth of 10.5 m and 74,500 m^2.
- Balearia Terminal: This terminal is dedicated to ferry traffic with Balearic Islands. It has 115 m quay long with a maximum draught of 9 meters and 13,000 m^2.
- Cruise Berths: This is an area located in the new extension of the port. It has 870 m quay long with a maximum draught of 14.

Figure 23. Port of Valencia Map
Source: web page of Valencia Port Authority

Valencia handles traffic of practically all types of goods from every sector of the economy. The main customers of the Port of Valencia include: the furniture and timber industries, textiles, footwear, agriculture and foodstuffs (grain and fodder, wine and beverages, tinned food, fruit, etc.), fuel products (diesel fuel, petrol, coal, etc.), chemical and motor vehicles (Ford, Fiat, Land Rover, Jaguar, etc.), the construction industry (cement and clinker, ceramic tiles, marble, etc.), machinery, etc.

The Port of Valencia also has regular passenger traffic to and from the Balearic Islands and Italy. In recent years the Port of Valencia has experienced a continued and solid growth in Mediterranean cruise traffic.

The total throughput in 2019 at the port of Valencia was 73,717,397 tons, with an increase of almost 5% (3 million tons) from the previous year. Most of the traffic corresponds to containerized cargo (60 318 952 tons, 82%); 14% corresponds to general cargo (10,200,466 tons, 14%); 1.53 million tons are solid bulks (2%) and 1.34 million tons are liquid bulks (2%). Total containers throughput was 5.4 millions, 5% more than in 2018, with a transhipment rate of 58%. Passengers traffic was slightly more than one million people, of which 435,616 corresponded to cruise and the rest to ferries traffic with the Balearic Islands. Finally, the port handled 565,430 vehicles.

The Port Authority of Valencia is also responsible for the management of two other ports, the port of Sagunto in the north and the port of Gandía in the south.

The port of Sagunto is mainly dedicated to the traffic of general cargo (4,020,059 tons), mainly steel products (2.25 million tons), as well as liquid bulks (1,752,675 tons), mainly liquefied natural gas (1.55 million tons). In 2019 the total traffic for this port was 6,961 318 tons.

On the other hand, the port of Gandía is the smallest of the three, with a total traffic of 386,125 tonnes in 2019, most (365,345 tonnes, a 95%) corresponds to general cargo, of which 81,000 tons are wood and cork and 125,000 paper and pulp.

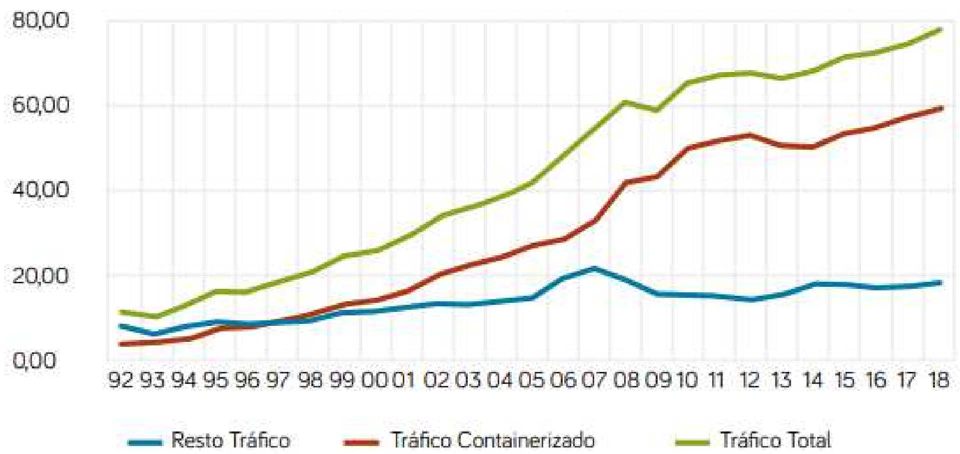


Figure 24. Valenciaport traffic evolution (million tons)
Source: web page of Valencia Port Authority

<u>Challenges:</u>

The port of Valencia is a port affected by the Mediterranean climate, so, in general, the main factors to consider are heat waves and cyclical submergence.

With regards to port operations, the climatic actions that affect them the most at present are the closure of the port due to the state of the sea and gusts of wind. Depending on the degree of increase in the frequency of events such as heat waves or torrential rains, they could also significantly affect operations.

The increased intensity and frequency of rainfall can cause flooding due to the failure of the drainage systems, as well as damage to warehouses, buildings and/or cargo, the failure of inland links (roads and railroads), affecting supply and distribution of goods to and from the ports. In addition to this, extreme precipitations events will affect operations leading to lost work time or even port closures.

For their part, high-speed winds can damage buildings, warehouses, cranes, and other port equipment, as well as navigation and communication equipment, which can cause delays and stoppages in cargo handling and make berthing difficult (requiring more tug assistance), or even impossible. They can also increase the wave action at waterfront structures and consequently an increase in overtopping rates, hence flooding of berth facilities, and more agitation of the port waters.

High temperatures and heat waves can affect infrastructures and building materials as pavements, steel, asphalt, and others. Also, they can affect the structure of equipment, engine cooling and cause power failures. Extreme temperatures can greatly worsen working conditions in berths and on board, and increase the energy demand for buildings, equipment cabins, warehouses cooling, and for container reefers.

Other possible effects are those related to wave regimes and storm surges. Changes in the prevailing wave directions can increase internal agitation. Breakwaters could be vulnerable to overtopping in storms combined with sea level rise that could cause flooding of facilities, damages in cargo, infrastructures and equipment.

6 EFFECTS OF CLIMATE CHANGE IN STUDY AREAS

6.1 Identification of Climate-related hazards methodology

Attending to IPCC, the definition of climate-related hazard is: "The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts".

As has been stated in the previous sections, coastal areas and Ports are affected nowadays by several climate-related parameters and processes. Climate change may alter the hazards associated to these parameters and even introduce new ones due to changes in the environmental conditions.

Although the climate-related hazards may vary from one area to another inside the SUDOE region, the methodology to identify these hazards in the three study cases (Aveiro, Bordeaux and Valencia) has been the same, with slight differences in the approach due to the idiosyncrasy of each area and the different actors involved.

One of the key factors to obtain a broader view and gather a better knowledge of the impact that all the environmental agents have in the multiple sectors involved in the coastal and port areas is to organize a local working group with as many stakeholders as possible.

Local knowledge and expert judgement that can be provided by this working group can be often sufficient to identify and classify the different climate hazards and the severity of the impact to the different activities.

Knowledge database from previous reports and projects in the areas of study can also provide valuable information when some of the blue economy elements are not identified or covered by the local working group expertise.

For the evaluation of climate-related hazards in the Ports of Aveiro, Bordeaux and Valencia, a local working group has been organized in each site with the Port Authority and the main stakeholders and port community involved in the operations and port activity. For the coastal areas, the information has been obtained from previous reports and projects done in these areas.

6.2 Coastal areas

Although some expertise from local working group has been used in the assessment of the climate-related hazards and the environmental variables related to each hazard, mainly the information used in this report has been obtained from existing literature from previous reports and projects that have been carried out in the areas studied.

Interrelationship of the different elements that are covered in Coastal Areas is complex and may vary along each coastal area, due to the different uses and activities carried out. As an example, coastal tourism is affected by several environmental variables as can be water quality, air temperature, water temperature, drought, but also is affected by modifications along the coastal strip which is affected by other environmental variables, as wind or waves. As a result, all the elements that have been described in the coastal area section will be considered as a whole, avoiding the duplication or redundancy of different climate-related hazards.

Attending to Losada (2014), most of the main coastal climate-related hazards and the environmental agents or variables that are involved in the hazard are covered in Table 7~~Table 7~~.

Table 7 Coastal climate variable and effects

Climate effects	Climate variables						
	Sea Level	Cyclones	Wind	Waves	Water temperature	Fresh water supply	Increased atmospheric concentration of CO2
Submersions	X						
Damage caused by coastal flooding	X	X					
Coastal erosion	X	X		X			
Saltwater intrusion	X	X					
Changes in the groundwater level	X	X					
Change and loss of marshes	X	X					
Storm surge		X	X				
Damage to infrastructure and protection works		X	X	X			
Wind waves			X				
Changes in wind transport for dune formation			X				
Changes in infrastructure operation and stability				X			
Change in water					X		

stratification and circulation			
Increased coral bleaching and mortality	X		
Species migration	X		
Algae growth	X		
Decrease in dissolved oxygen	X		
Change in the risks of flooding in the lower course of rivers		X	
Changes in water quality and salinity		X	
Alteration of the sedimentary contributions of the rivers		X	
Alterations in circulation and nutrient inputs		X	
Increased CO2 in the ocean/sea			X
Increased CO2 fertilization			X
Decrease in water pH			X

Source: *Losada et al. (2014)*.

6.2.1 Aveiro

Attending to the available documentation in the coastal lagoon area of Aveiro, based on previous reports, papers and thesis, the main climate-related hazards affecting this area are the following ones:

Table 8 Climate related hazards in Aveiro coastal areas

Climate variable	Climate-related hazard	Impact
Coastal erosion		
Storm surge	• Erosive retreat of beaches with a reduction of the total useful surface or a displacement of the same	• Erosion along coastline
Waves	• Changes in mean offshore wave conditions • Changes in the wave direction	• Erosion along coastline
Sea level rise	• Erosive retreat of beaches with a reduction of the total useful surface or a displacement of the same	• Erosion along coastline
Flooding		
Storm surge	• Increased risk of coastal flooding	•
Rainfall	• Personal injury from flooding and overflows • Damage to service infrastructure • Sediment transport modification • Overflowing of the sanitary drainage system and sewage treatment plants due to overloads • Low water level at the estuary • Electric production (hydroelectric power plants)	•
Sea level rise	• Increased risk of coastal flooding • Damage to coastal infrastructure and buildings	
Overtopping	• Risk of coastal flooding	
Water quality		
Salinity	• Aquaculture • Agriculture	• Changes in the salinity of the lagoon

		affecting the ecosystem
Suspended soils	• Accretion at mouth of the estuary	

Source: Own elaboration

6.2.2 Bordeaux

The following table summarizes the different climate-related hazards and related parameters affecting the coastal area of the estuary of Gironde, where Bordeaux Port is located.

Table 9 Climate related hazards in Bordeaux coastal areas

Climate variable	Climate-related hazard	Impact
Coastal erosion		
Storm surge	• Erosive retreat of beaches with a reduction of the total useful surface or a displacement of the same	• Erosion at mouth of estuary
Waves	• Changes in mean offshore wave conditions • Changes in the wave direction	• Erosion at mouth of estuary
Sea level rise	• Erosive retreat of beaches with a reduction of the total useful surface or a displacement of the same	• Erosion at mouth of estuary
Flooding		
Storm surge	•	•
Rainfall	• Personal injury from flooding and overflows • Damage to service infrastructure • Soil contamination • Sediment transport modification • Overflowing of the sanitary drainage system and sewage treatment plants due to overloads • Low water level at the estuary • Electric production (hydroelectric power plants)	• Drowning, hypothermia, physical injury, traffic accidents, etc • Interruptions in the supply of basic services to the population (water, food, electricity, health, etc.). • Intrusion of pathogenic microorganisms in the sources of water for human consumption

		and the consequent increase in diarrheal diseases • Water production shortage
Sea level rise	• Increased risk of coastal flooding • Damage to coastal infrastructure and buildings	
Overtopping	• Risk of coastal flooding	
Water quality		
Water temperature	• Aquaculture • Electric production (nuclear power station)	• Reduction of fishery • Blayais nuclear power plant
Salinity	• Aquaculture • Electric production (nuclear power station) • Agriculture • Water treatment	• Reduction of fishery
Suspended soils	• Sewage water emission	
Oxygen in water	• Aquaculture	

Source: Own elaboration

6.2.3 Valencia

The following table summarizes the different climate-related hazards and related parameters affecting the coastal area of Valencia. Mainly, the hazards are related to the coastal strip, which affects also to other blue economy sectors, such as coastal tourism or aquaculture.

Table 10 Climate related hazards in Valencian coastal areas

Climate variable	Climate-related hazard	Impact
Coastal erosion		
Storm surge	• Erosive retreat of beaches with a reduction of the total useful surface or a displacement of the same	
Waves	• Changes in mean offshore wave conditions • Changes in the wave direction	

Sea level rise	• Erosive retreat of beaches with a reduction of the total useful surface or a displacement of the same	• Greater seawater penetration in L 'Albufera. • Reduction of the marshes.
Rainfall	• Sedimentation at the mouth of the rivers, ravines and ditches by dragging materials.Soil damage due to drainage overload: • Foundation damages	
Flooding		
Rainfall	• Personal injury from flooding and overflows: • Damage to service infrastructure • Overflowing of the sanitary drainage system and sewage treatment plants due to overloads	• Drowning, hypothermia, physical injury, traffic accidents, etc • Interruptions in the supply of basic services to the population (water, food, electricity, health, etc.). • Intrusion of pathogenic microorganisms in the sources of water for human consumption and the consequent increase in diarrheal diseases
Sea level rise	• Increased risk of coastal flooding • Damage to coastal infrastructure and buildings	
Water quality		
Reduction in average rainfall	• Reduction of surface courses and water recharge in the subsoil. • General decrease in the availability and quality of water for consumption. • Over-exploitation of the coastal aquifer: saline intrusion	• Increase in the price of water. • Conflicts over the use of water. • Decrease of water sheet in L 'Albufera and increase of its salinity.
Increase in average temperatures	Increased air temperature: • Increased demand for water resources by sectors with increased evapotranspiration.	• Over-exploitation of aquifers. • Conflicts over the use of water and an increase in its price due to increased

	• Reduction of the circulating flow in watercourses and seasonal drying in some sections. Increased water temperature: • Increase in pathogens in the water which results in a deterioration of water quality associated with health damage and an increase in the cost of water treatment. • Increase in the concentration of bacteria in wastewater and drainage.	water pressure and a reduction in availability. • Likelihood of toxic cyanobacterial blooms in the Turia River and the Albufera • Reduction in the quality of fresh water.
Droughts	• Hydrological drought: unavailability of water in the subsoil. Over-exploitation of aquifers • Imbalances in water availability/demand. • General decrease in the availability of water for consumption • Accelerated nitrification of aquifers	• Increase in water prices. • Conflicts over water use. • Poor water quality • Reduction of the recharge of L'Albufera.
Temperature		
Increase in average temperatures	Increased air temperature: • Increase in evapotranspiration and water demand of vegetation • Increased risk of entry and establishment of invasive species. • Changes in the migratory and reproductive patterns of fauna as a result of more benign winters. • The urban heat island effect amplifies the detrimental effects of high temperatures • Alteration of the sea breeze system • Advancement of the flowering of some woody species of spring flowering, prolonging their pollen	• Changes in tree density and distribution of plant species. • Greater colonization of the perforating or defoliating species due to the more benign winters. • Increased morbidity, mortality and hospital admissions of the most vulnerable people due to heat stress in urban heat islands. • Increased incidence of heat stress related conditions: heat stroke,

	season, and the exposure of the sick • Acceleration of the development of the mosquito, increasing the rate of bite and inoculation. • Increased levels of tropospheric ozone and other air pollutants that aggravate cardiovascular and respiratory diseases. • Increased risk of Legionella due to the increased use of air conditioning systems. • Increased risk of salmonellosis.	exhaustion, cramps, rashes, dehydration, heat syncopes, arrhythmias and aggravation of illness. • air circulation in the city reduced • Increase in the seasonality and severity of allergic diseases such as asthma, rhinitis, allergic conjunctivitis or some dermatitis • • Stable presence of the mosquito vector of malaria, leishmaniasis, dengue and Chikungunya
	Increased water temperature: • Increased eutrophication. • Increased thermal stratification and its effects. • Alteration of marine food webs, as well as in the distribution of species • Increased vulnerability of longer-lived and slower-growing organisms • Increase in waterborne pathogens and potential health damage	• Anoxia in La Albufera. • Earlier emergence of aquatic insects. • Proliferation of invasive species • Drastic increase in jellyfish population • Regeneration in artificial reefs at risk • Posidonia meadows regression. • Increased presence of jellyfish, cyanobacteria and red tides. • Increase in species of toxic phytoplankton or parasites of cultivated species. • Reduction in the productivity of bivalve farms (and increased risk of poisoning by contamination of

		toxins from micro algae.
Droughts	• Increased pressure on water resources and consequently the salinity of the water in L'Albufera,Reduction of water availability for tree irrigation. • Water stress of vegetation due to increased evapotranspiration and water deficit. • Increased drying and flammability of plant biomass	• Alterations in the local ecosystem: fauna and flora • Proliferation and attack of drilling or defoliation species • Increased intensity, frequency and duration of fire risk

Source: Own elaboration

6.3 Ports

To determine climate-related hazards affecting ports, all the interdependencies between the different operations, activities, and systems, both inner and external to ports must be analysed. Even though expert judgement can provide valuable information for an initial approach, the creation of a local working group involving the main stakeholders that have their activity at the port is a desirable requisite.

Three local working groups have been organized in ECCLIPSE, one in each Study Case: Aveiro, Bordeaux, and Valencia. Each location has its own idiosyncrasy and thus, the stakeholders joining the working group differ from one location to another.

Port Authority is the main stakeholder in each working group as they gather the knowledge, not only for the infrastructures and the hazards affecting them, but also the operations and the hazards that force operative stops inside the port.

Companies developing part of their activity inside the port can provide not only their knowledge to their specific activities, but also the sensed risk of each hazard. The evaluation of these sensed risks can help determining the criticality of the hazard.

Main hazards that can affect the different ports are the following ones:

- Overwhelmed drainage systems
- Flooding
- Wave Overtopping affecting protected areas of the port
- High current velocities in channels and port mouths
- Changes in sediment transport, deposition and erosion affecting bathymetry
- Reduced visibility
- Port agitation
- Ship manoeuvres inside and outside port
- Changes in wind speed and/or direction
- Heat and Cold waves (air temperature)
- Damages in infrastructures

These hazards can be provoked by the following climate parameters and processes:

Table 11 Relationship between climate-related hazards with parameters and processes

Hazard	Sea level rise	Storm surge	Currents	Waves	Wind	Precipitation	Fog	Air temp
Overwhelmed drainage systems	X	X				X		
Flooding	X	X				X		
Wave overtopping	X	X		X	X			
High current velocities	X			X	X			
Changes in bathymetry	X		X	X				
Reduced visibility							X	X
Port agitation				X				
Ship manoeuvres				X	X			
Changes in wind speed/direction					X			
Heat/Cold waves								X
Damages in infrastructures	X	X	X	X	X	X		

Source: Own elaboration

To evaluate the sensed risk of each hazard, a common classification of risk severity has been used for the 3 study cases:

Table 12 Impact classification for port operations

Impact level	Operations
Severe/Critical	Affection to the activity due to the number of times the operations has to be stopped due to this environmental variable risk long-term viability of business and supply chain
High	Serious affection to the supply chain and economic impact due to the number of times the operation must be stopped due to this environmental variable. Intervention require significant remedial actions to protect business continuity
Moderate	The number of times the operation has to be stopped due to this environmental variable affects the supply chain and has an economic impact. This affection requires some minor actions to protect business continuity
Low or Insignificant	The number of times the operation has to be stopped due to this environmental variable does not affect the supply chain or has been considered as a normal situation in the annual activity planning.

Source: Own elaboration

All this information has been gathered using surveys and meetings to identify hazards and risks, which are developed in the following subsections.

6.3.1 Aveiro

The initial selection of climate hazards that affect Aveiro with actual climate or can affect due to climate change are the following:

- Flooding
- Overwhelming of rainwater drainage systems due to sea level or storm surge
- Ship entry and exit manoeuvres hampered by increased intensity of currents
- Ship entry and exit manoeuvres hampered by wave height
- Ship entry and exit manoeuvres hampered by wave direction variation
- Solid bulk operations restricted by wind changes
- Port operations restricted by rainfall
- Low visibility
- Increased sedimentary regime in navigation channel
- Damage in infrastructures due to higher waves
- Damage in infrastructures due to atmospheric parameters

A survey with these hazards was elaborated and shared with the local working group, to identify which of these hazards could affect the different operations and port infrastructures and the sensed risks, considering low, moderate and high impact.

As a summary the following climate-related hazards, with the associated sensed risk, assuming the most unfavourable situation, is shown in the following table:

Table 13 Sensed risk for climate-related hazards in Aveiro Port

Hazard	Sensed risk
Flooding	high
Overwhelming of rainwater drainage systems due to sea level or storm surge	high
Ship entry and exit manoeuvres hampered by increased intensity of currents	High
Ship entry and exit manoeuvres hampered by wave height	moderate
Ship entry and exit manoeuvres hampered by wave direction variation	low
Solid bulk operations restricted by wind changes	moderate
Port operations restricted by rainfall	high
Low visibility	high
Increased sedimentary regime in navigation channel	high
Damage in infrastructures due to higher waves	high
Damage in infrastructures due to atmospheric parameters	high

Source: Own elaboration

6.3.2 Bordeaux

The following climate-related hazards have been pre-identified in Bordeaux port, in collaboration with the Bordeaux Port Authority:

- Heat waves
- Water temperature (high)
- Waves
- Wind speed
- Flooding
- Heavy rainfall
- Humidity
- Currents reduction
- Sedimentary dynamics modification
- Increase in salinity
- Fog

A survey with these hazards was elaborated and shared with the local working group, to identify which of these hazards could affect the different operations and port infrastructures and the sensed risks, considering low, moderate, and high impact. As a summary the following climate-related hazards, with the associated sensed risk, assuming the most unfavourable situation, is shown in the following table:

Table 14 Associated impacts for climate-related hazards in Bordeaux Port

Hazard	Sensed risk
Ship entry and exit manoeuvres hampered by increased intensity of currents	high
Ship entry and exit manoeuvres hampered by wave height	high
Flooding of port areas	high
Ship entry and exit manoeuvres hampered by wind speed	high
Solid bulk operations restricted by wind changes	high
Port operations restricted by rainfall	moderate
Low visibility	moderate
Increase of dredging operations due to changes in sedimentary regime	high
Damage in infrastructures due to higher waves	moderate
Damage in infrastructures due to atmospheric parameters	moderate

Source: Own elaboration

6.3.3 Valencia

The potential climate-related hazards that have been selected in Valencia Port are the following ones:

- Heat waves
- Increase in water temperature
- Maritime activities and manoeuvres outside the port
- Limited port operations due to port agitation
- Limited port operations due to wind
- Overtopping
- Flooding
- Low water level at Port mouth (bathymetry changes)
- Low visibility
- Heavy rainfall
- Electric storms

During the survey, the identification of the hazard was linked to each of the different environmental variables that provoked that hazard. Attending to the given answers, the main variables that lead to hazards are air temperature, waves, wind and fog.

As a summary the following climate-related hazards, with the associated environmental variables and sensed risk is shown in the following table:

Table 15 Sensed risk for climate-related hazards in Valencia Port

Hazard	Sensed risk
Heat waves	Low
Increase in water temperature	low
Maritime activities and manoeuvres outside the port	high
Limited port operations due to port agitation	low
Limited port operations due to wind	high
Overtopping	low
Flooding	low
Low water level at Port mouth (bathymetry changes)	low
Low visibility	moderate
Heavy rainfall	moderate
Electric storms	moderate

Source: Own elaboration

7 CONCLUSIONS

In this document, a review of previous projects, reports and papers covering the influence of environmental parameters and processes in the blue economy sectors, coastal strip and port activity has been done in chapters 3 and 4, providing a common framework to develop the assessment of the climate-related hazards that can affect each of the study areas covered in the ECCLIPSE project.

From this analysis of the state of the art, it can be concluded that the evaluation of climate-related hazards in the coastal and port areas of the SUDOE region is a complex activity that involves analysing several interdependencies between sectors and evaluating cascade effects of risks.

The creation of a local working group, with different stakeholders from the area of study, can provide valuable expertise knowledge on the different interdependencies and impacts of the hazards and the activities that are carried out.

Although a common methodology has to be done in order to assess the hazards affecting a coastal area or a port, each region involve different stakeholders and procedures, and the methodology has to be adapted to fit the local working group in a proper way.

Each type of coast and port has its own climate-related hazards, being some of them unique while others are shared. From the surveys and expert criteria, the climate-hazards affecting a specific area can be identified, but the following ones can be used as a first approach if no other information is available:

- Increase of water temperature
- Change in wave climate (direction and height)
- Change in wind climate (direction and speed)
- Sea level rise
- Flooding (rainfall+sea level+storm surge)
- Water quality
- Increase of air temperature

The impact that each of these hazards has in the different areas vary, but mainly affect the aquaculture and fishery sector, coastal tourism and changes in coastal strip due to erosion.

Attending to port infrastructures and operations, the main hazards are the following:

- Changes in wave climate (direction and height)
- Changes in wind climate (direction and speed)
- Sea level rise
- Overtopping
- Flooding

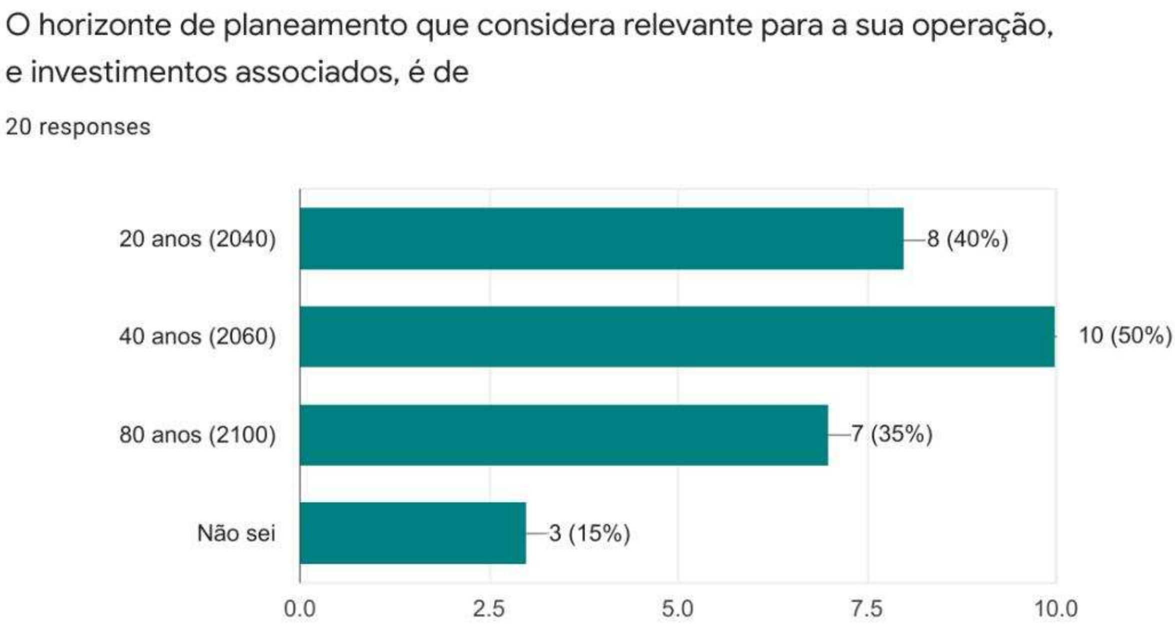
The real impact that these climate-related hazards have in the different areas of study must be validated by the projection of the different environmental variables and parameters for different climate change scenarios and time frames in the future.

8 ANNEXES

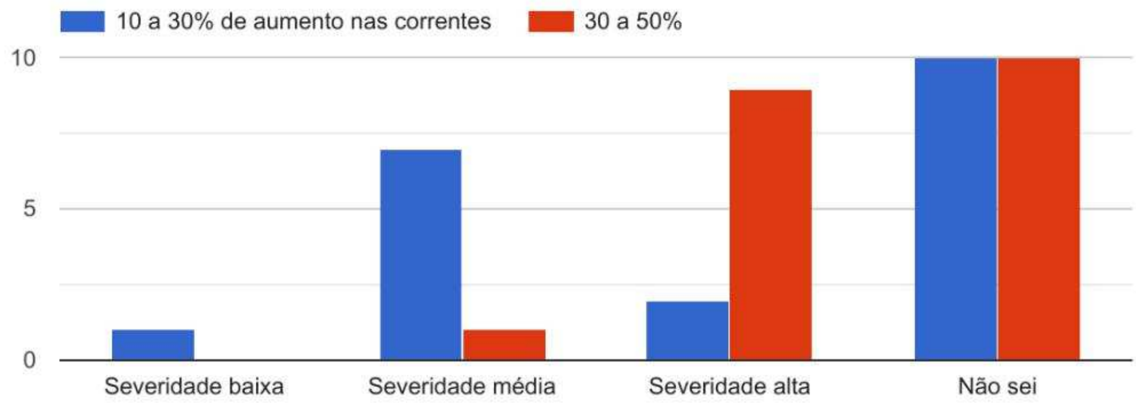
8.1 Questionaries

The following sections show the results of the surveys that have been done in each of the local working groups of Aveiro, Bordeaux and Valencia. This information has been analysed to obtain the results described in chapter 6.

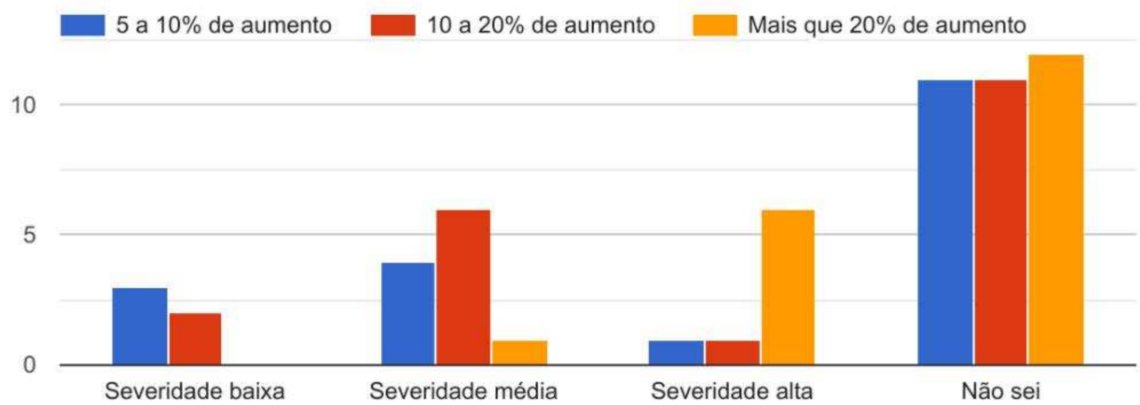
8.1.1 Aveiro



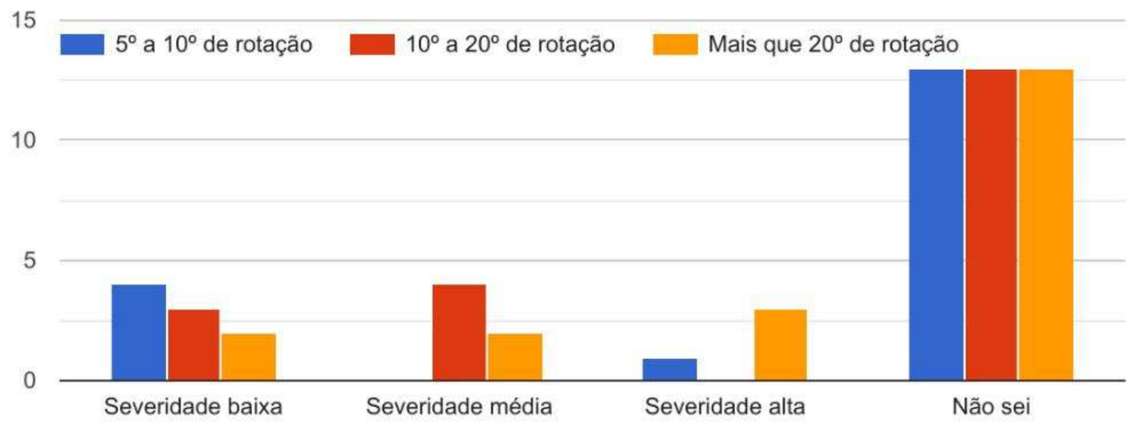
Manobras de entrada e saída de navios dificultadas pelo aumento da intensidade das correntes no canal de navegação



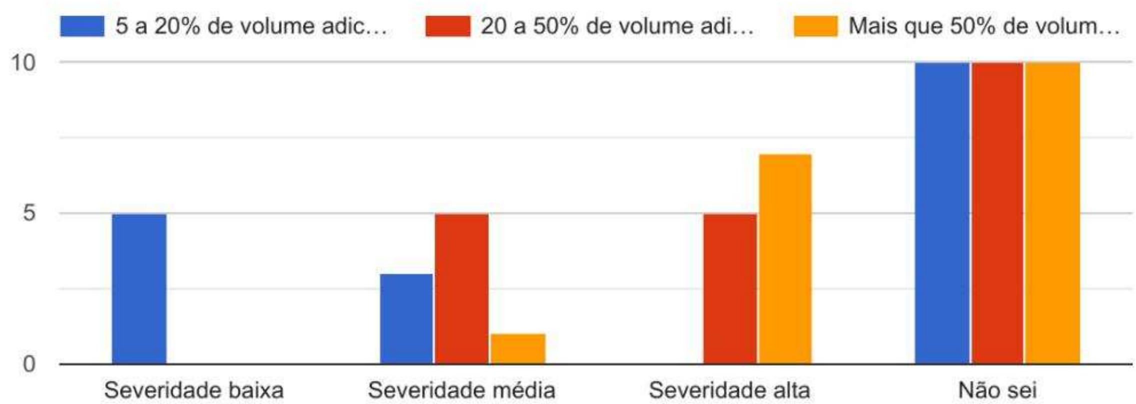
Manobras de entrada e saída de navios dificultadas pelo aumento da altura média da ondulação



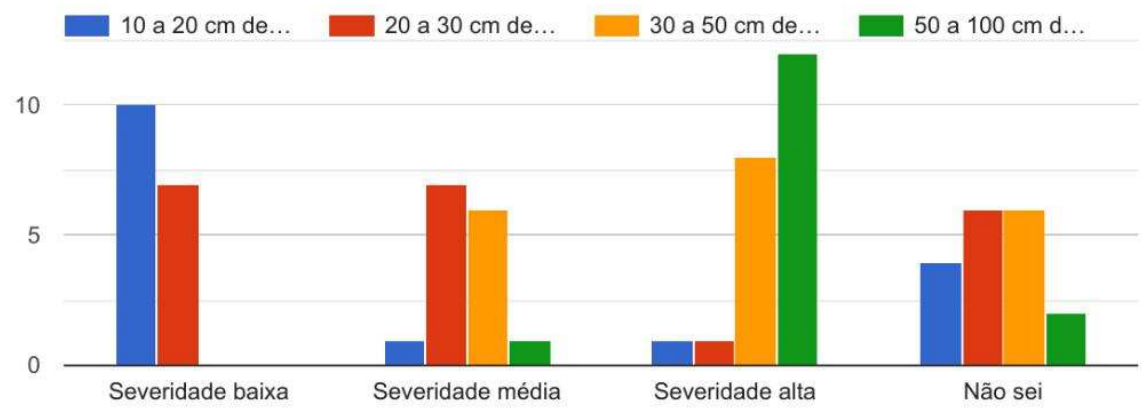
Manobras de entrada e saída de navios dificultadas pela rotação anti-horária (para Sul) da direcção média da ondulação



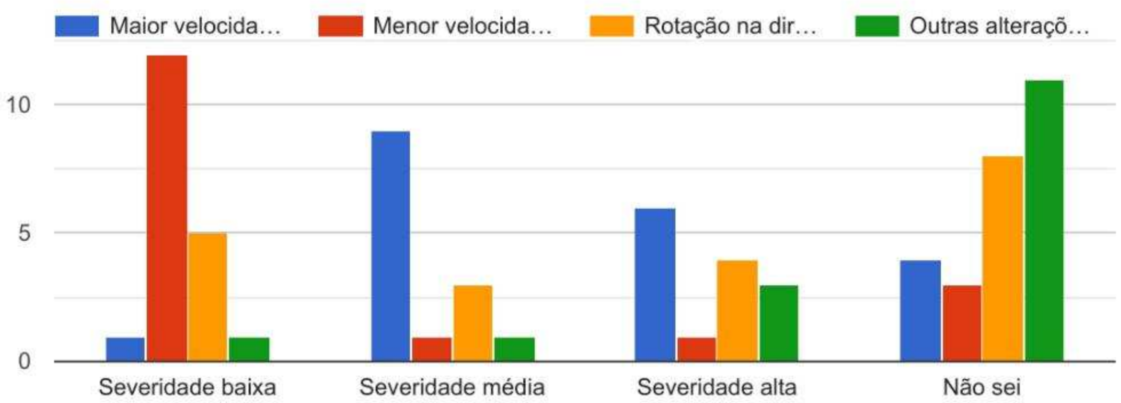
Aumento da frequência e volume das dragagens devido a alterações no regime sedimentar



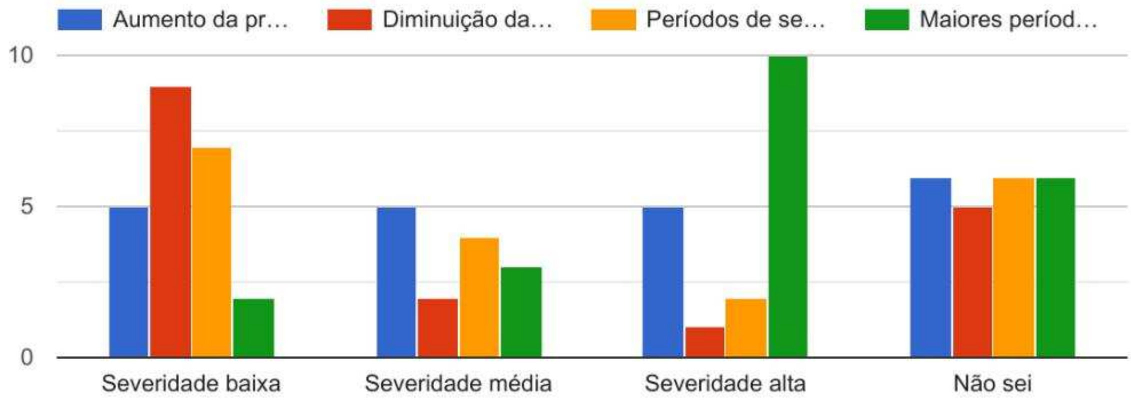
Inoperacionalidade e redução das áreas portuárias disponíveis por inundação, devido ao aumento do nível médio do mar



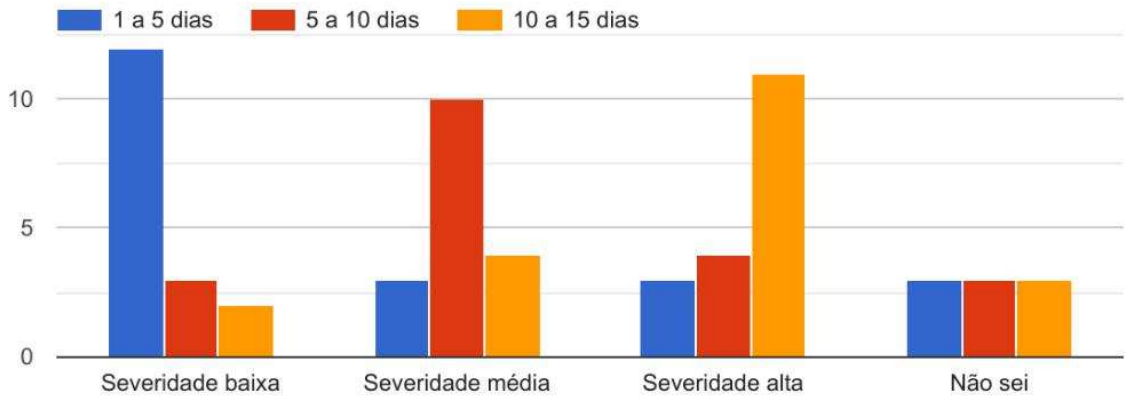
Restrições à movimentação de graneis sólidos e de carga geral devidas a alterações no regime de ventos



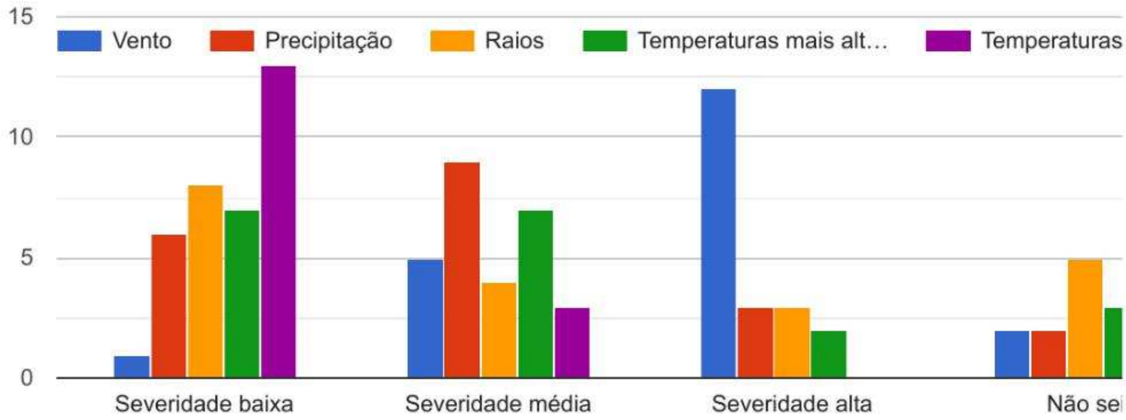
Restrições à movimentação de graneis sólidos e de carga geral devidas a alterações no regime da precipitação



Restrições à actividade portuária por aumento do número médio de dias de nevoeiro por ano

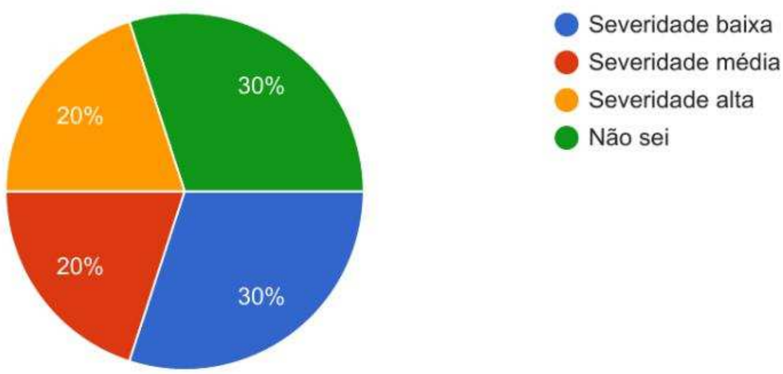


Danos nas estruturas terrestres devido ao aumento de fenómenos meteo-marítimos extremos

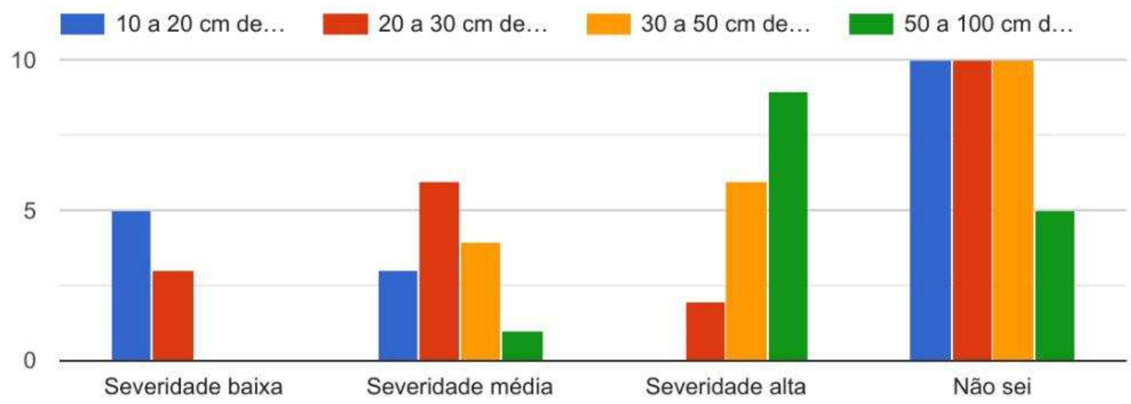


Aumento dos níveis de corrosão das infraestruturas devido à subida da temperatura e alteração de salinidades

20 responses

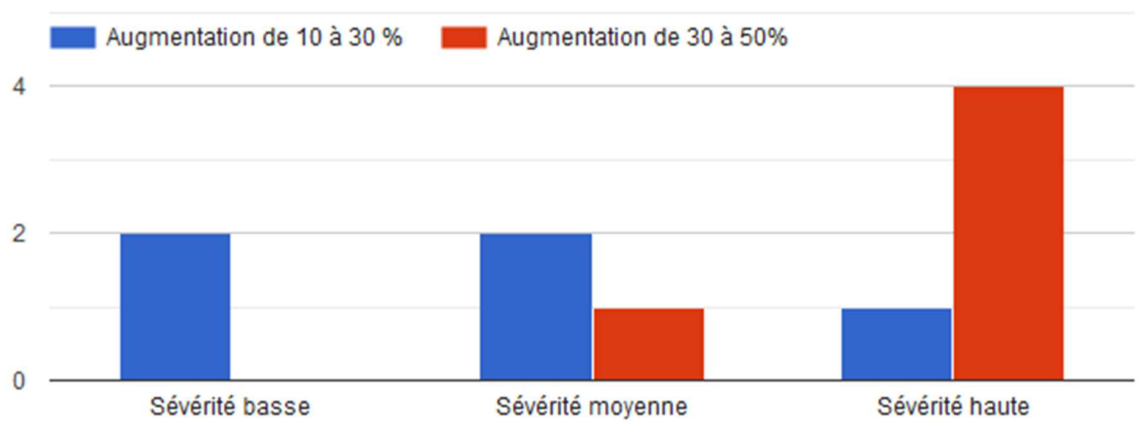


Restrições à drenagem das águas pluviais por aumento do nível médio das águas do mar e das elevações provocadas por fenómenos extremos

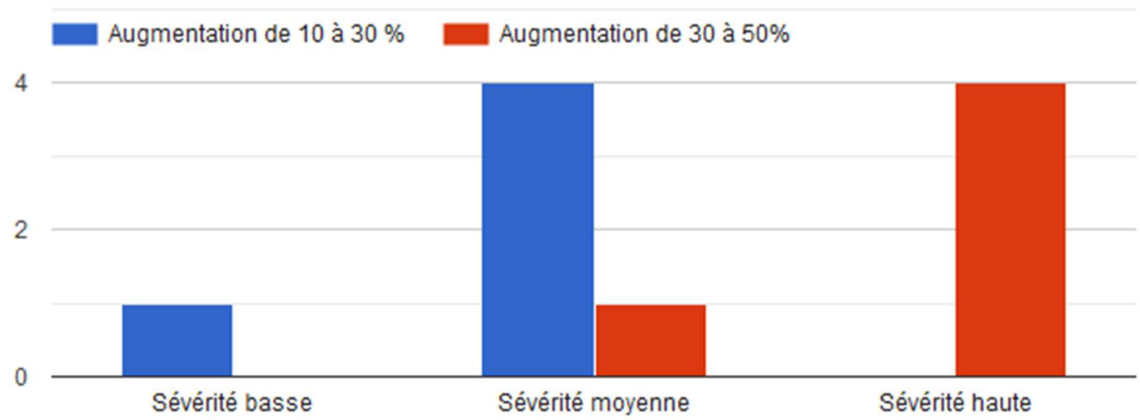


8.1.2 Bordeaux

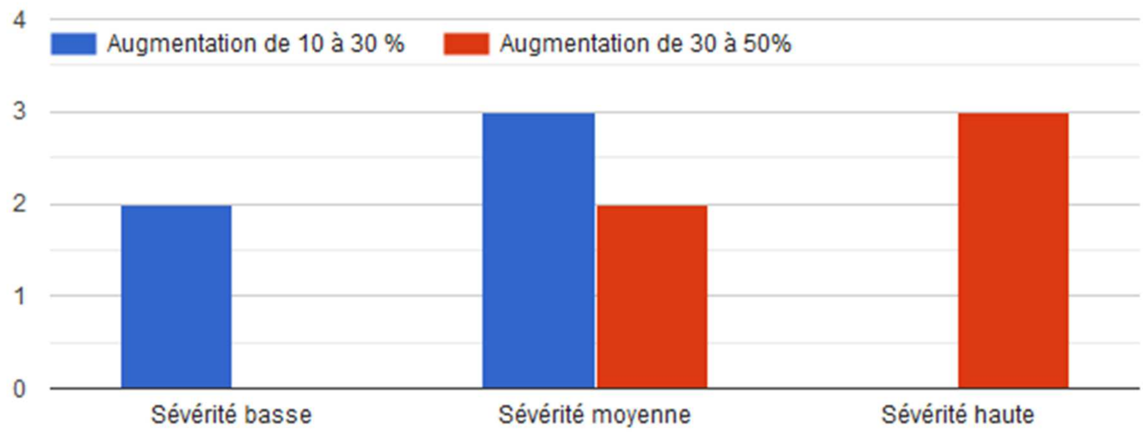
Impact d'une augmentation des courants sur les manœuvres d'entrée et de sortie des navires



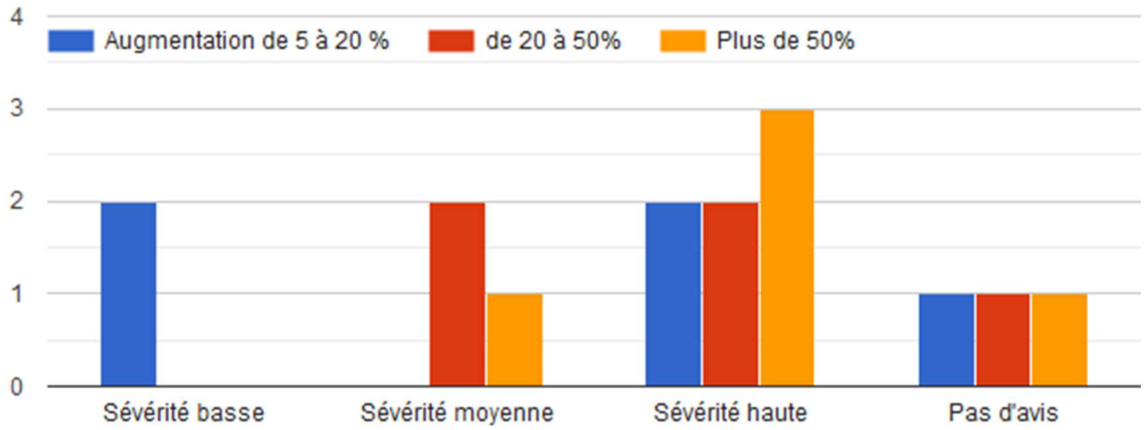
Impact d'une augmentation des hauteurs de houle sur les manœuvres d'entrée et de sortie des navires



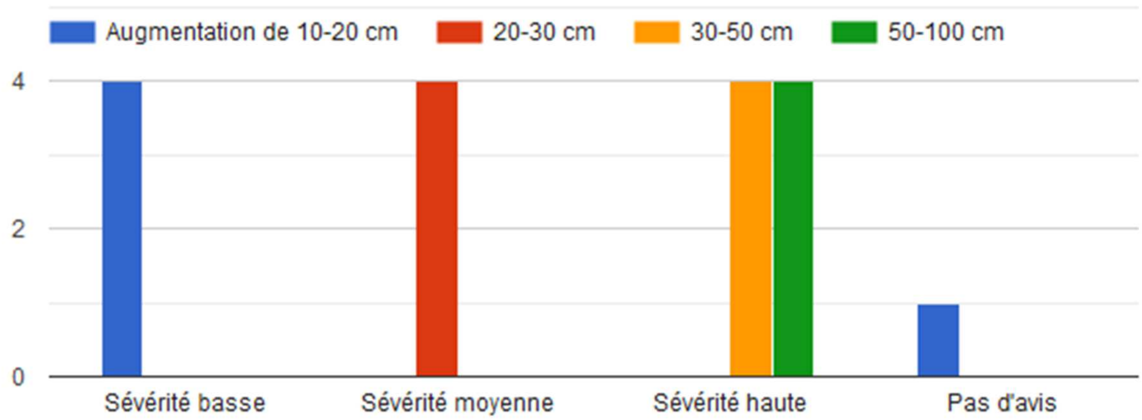
Impact d'une augmentation des niveaux de vent sur les manœuvres d'entrée et de sortie des navires



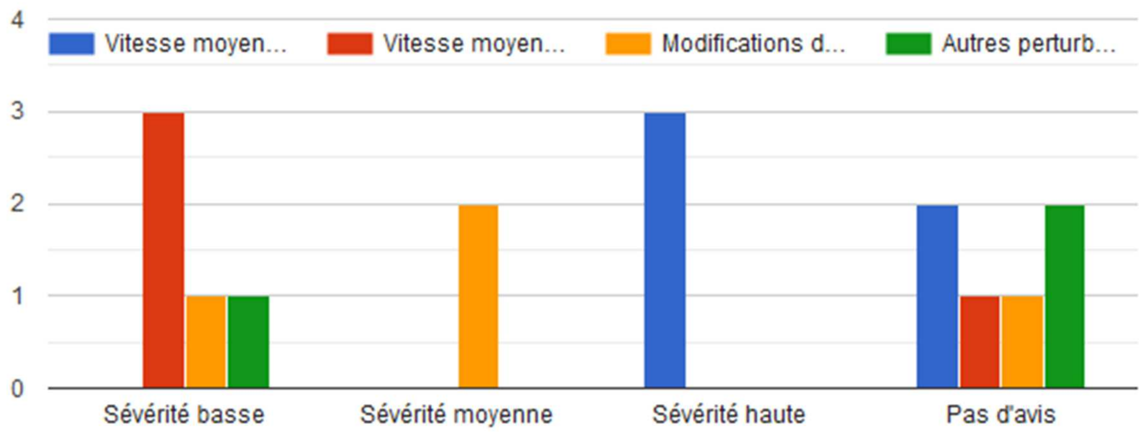
Impact d'une augmentation de la fréquence et des volumes dragués induite par une modification de la dynamique sédimentaire



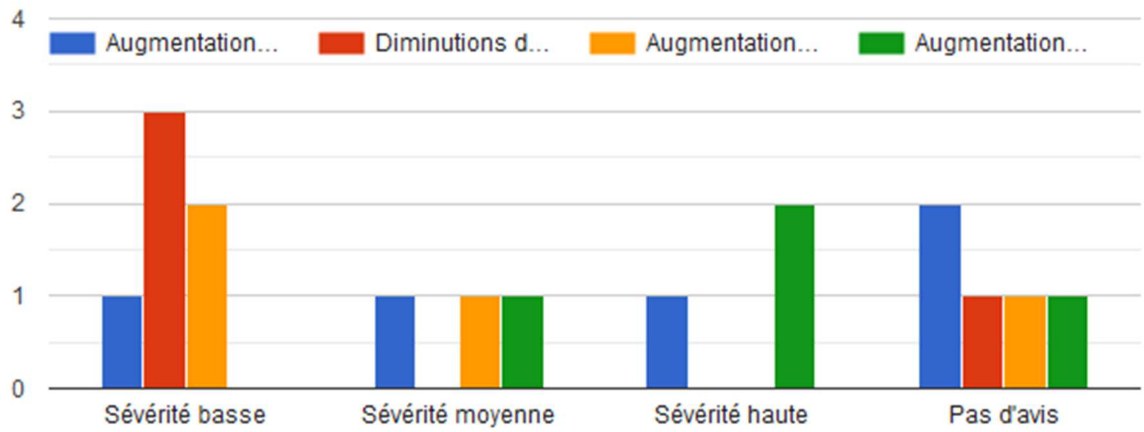
Impact d'une augmentation du niveau moyen sur la réduction des zones portuaires disponibles en raison des inondations,



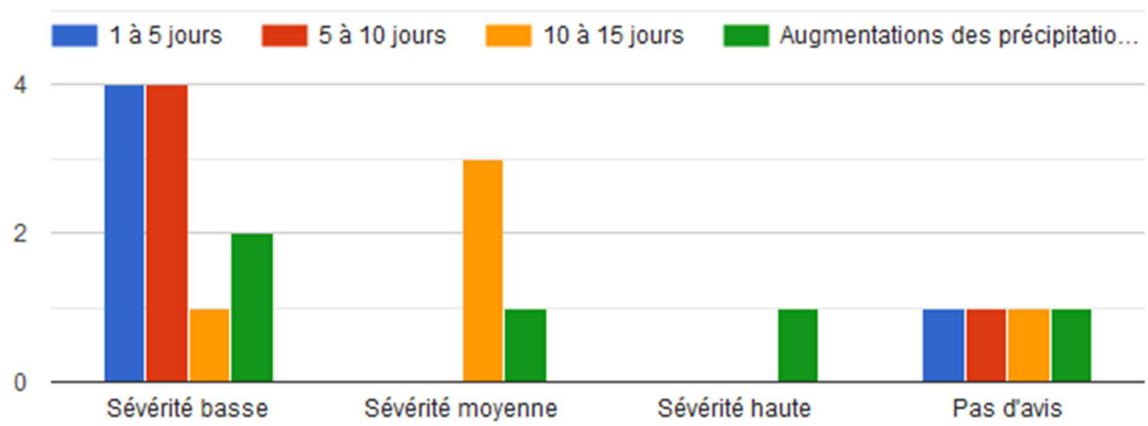
Restrictions au mouvement de vrac solide et du fret en général en raison de modifications du régime de vent



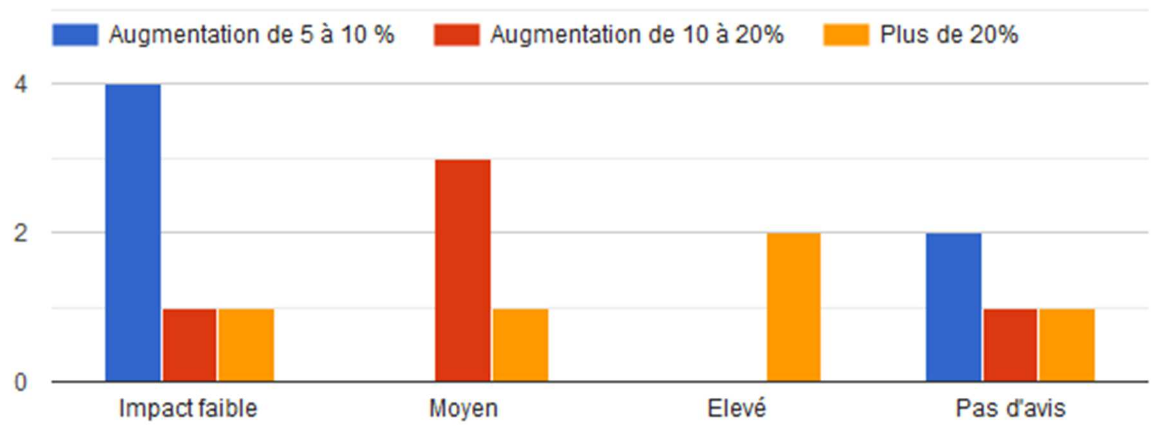
Restrictions au mouvement de vrac solide et du fret en général en raison de modifications du régime de pluie



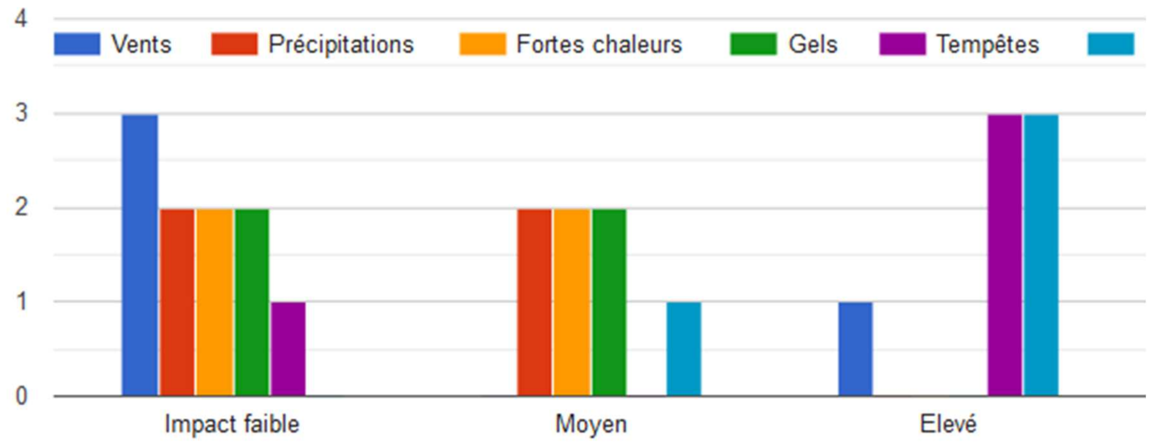
Restrictions à l'activité portuaire en raison d'une augmentation du nombre moyen de jours de brouillard par année



Dommages plus importants et effondrement possible de certaines structures maritimes en raison de l'augmentation des hauteurs moyennes de houle

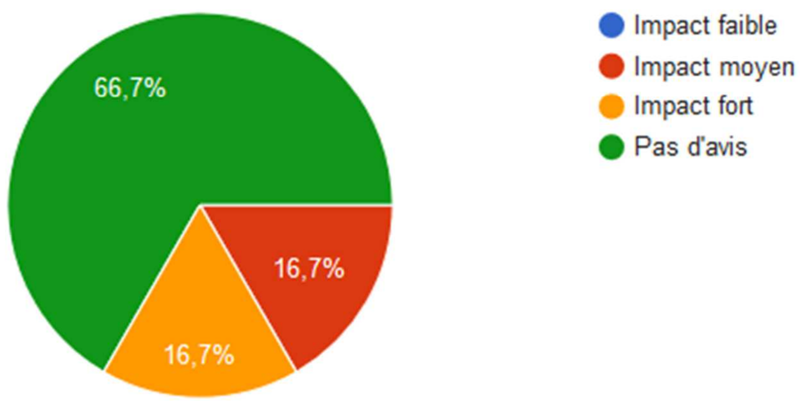


Dommages aux structures à quai dus à l'augmentation des phénomènes météorologiques et maritimes extrêmes

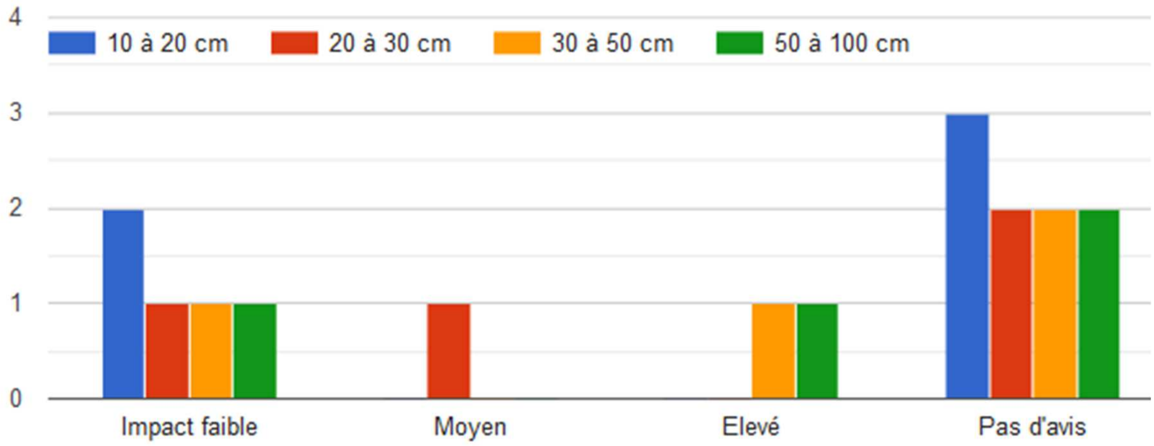


Augmentation des niveaux de corrosion dans les infrastructures en raison de la hausse des températures et changement de salinité

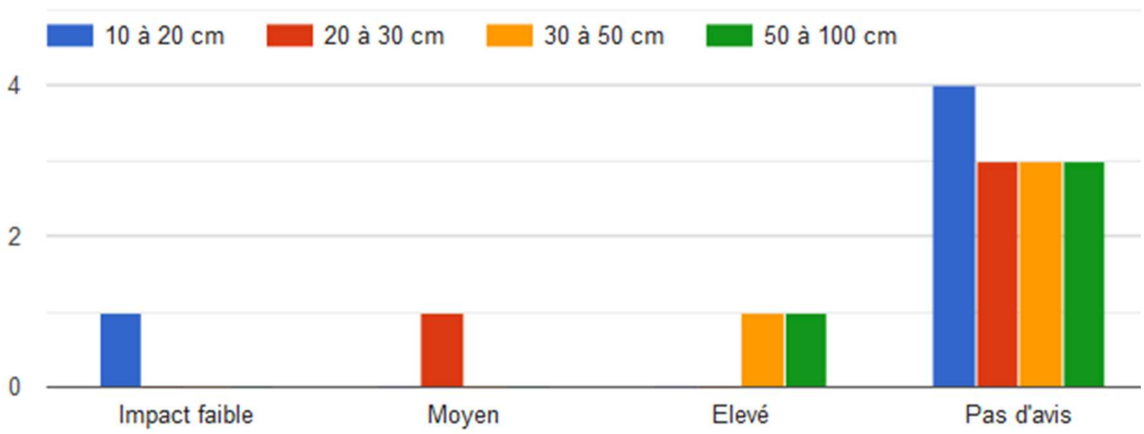
6 respuestas



Restrictions au drainage des eaux de pluie en raison d'une augmentation du niveau moyen de l'eau de mer et les élévations causées par des phénomènes extrêmes

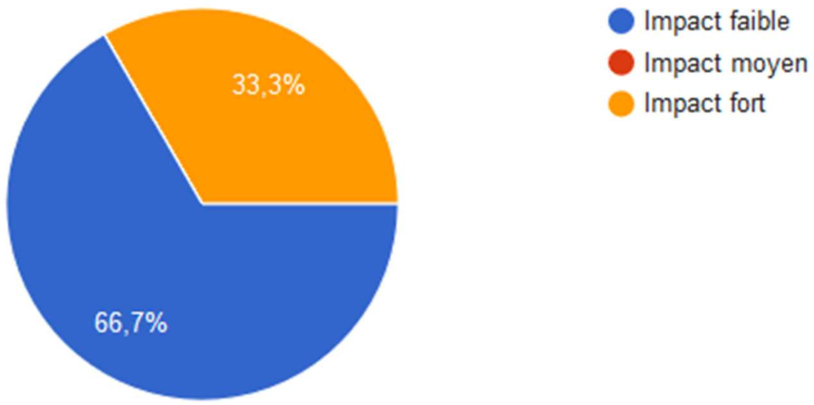


Restrictions au drainage des eaux de pluie en raison d'une augmentation du niveau moyen de l'eau de mer et les élévations causées par des phénomènes extrêmes



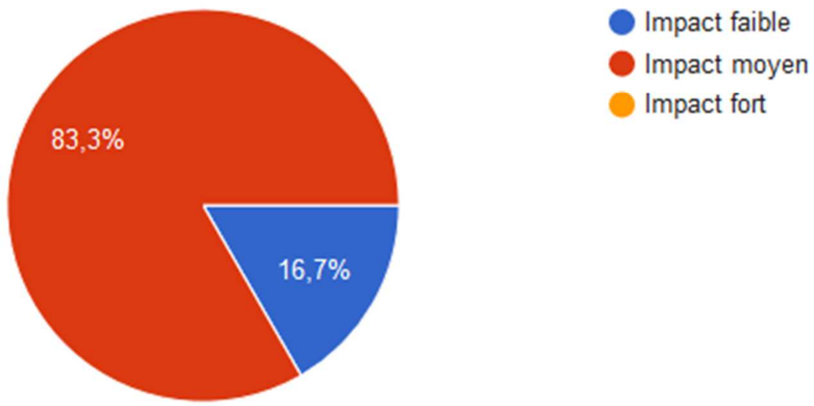
Augmentation de l'humidité sur la dégradation des céréales

3 respuestas



Augmentation du nombre de jours de canicule sur les conditions des travailleurs

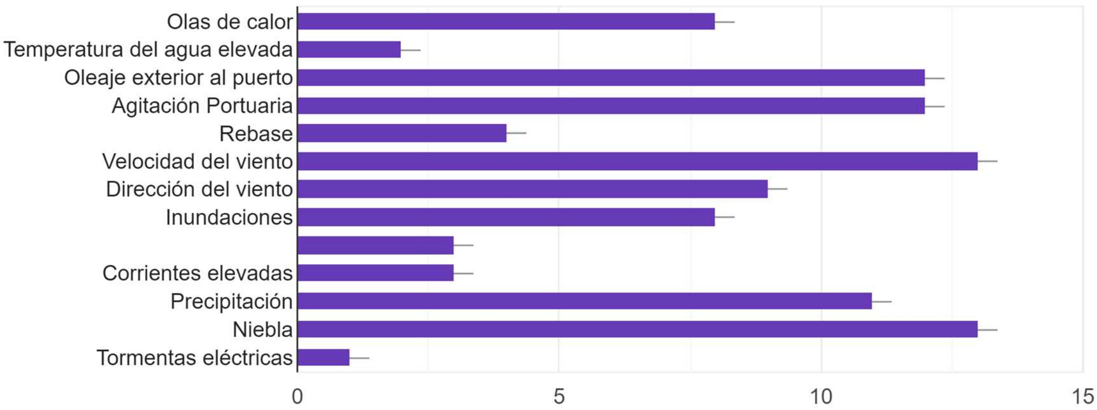
6 respuestas



8.1.3 Valencia

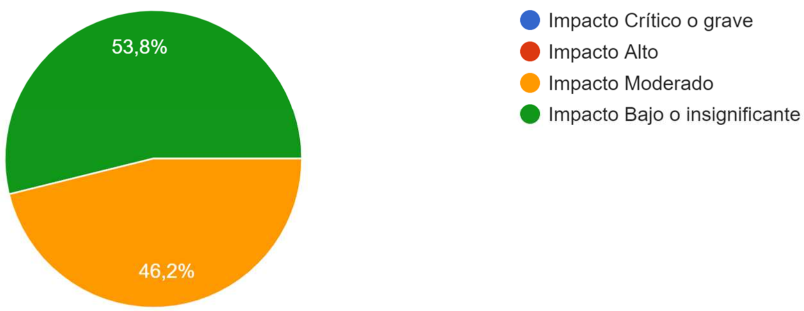
¿Qué fenómenos afectan o pueden afectar a la operativa que se realiza en el puerto?

14 respuestas



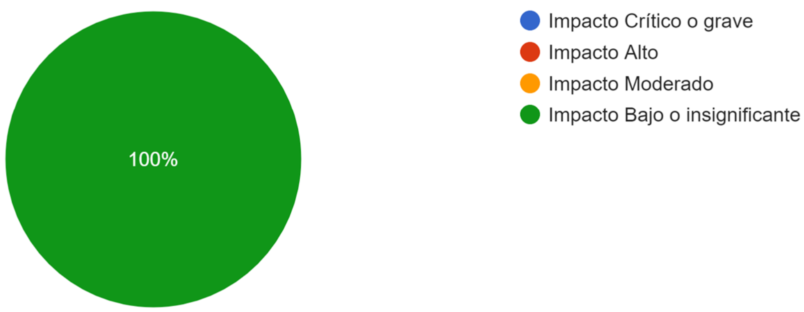
¿Cómo afecta a la operativa actual los episodios de ola de calor?

13 respuestas

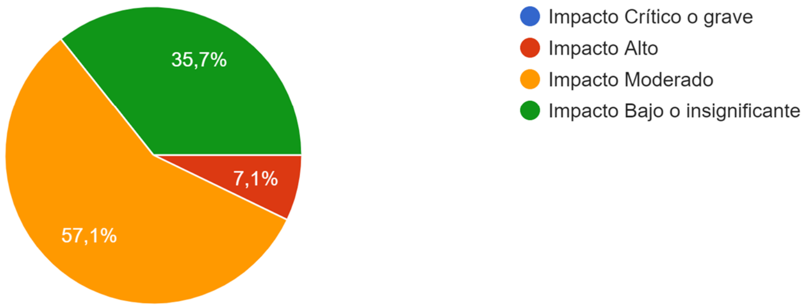


¿Cómo afecta a la operativa actual los episodios de temperatura del mar elevada?

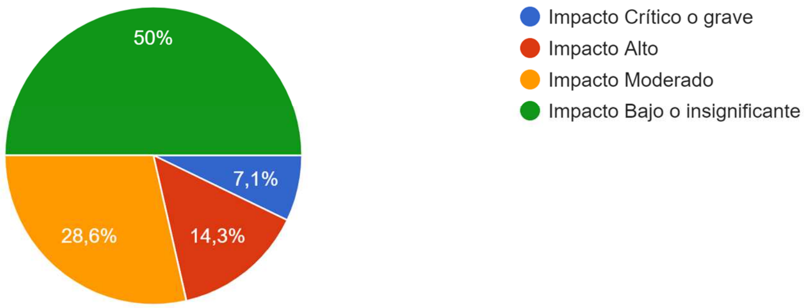
11 respuestas



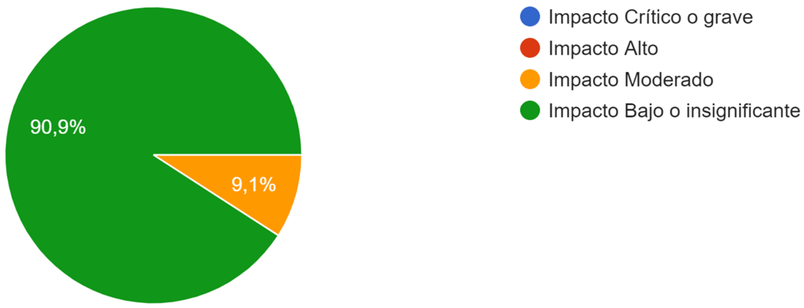
¿Cómo afecta a la operativa actual los episodios de oleaje exterior al puerto?
14 respuestas



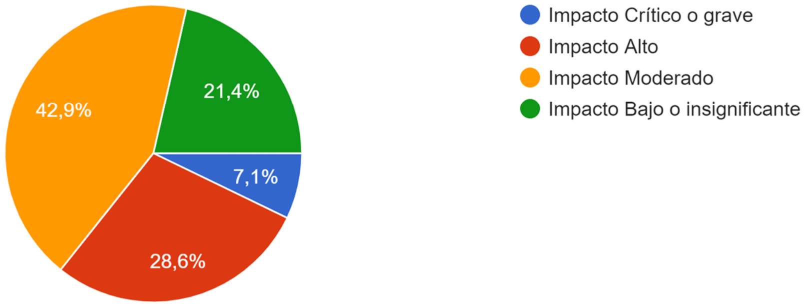
¿Cómo afecta a la operativa actual los episodios de agitación interior en el puerto?
14 respuestas



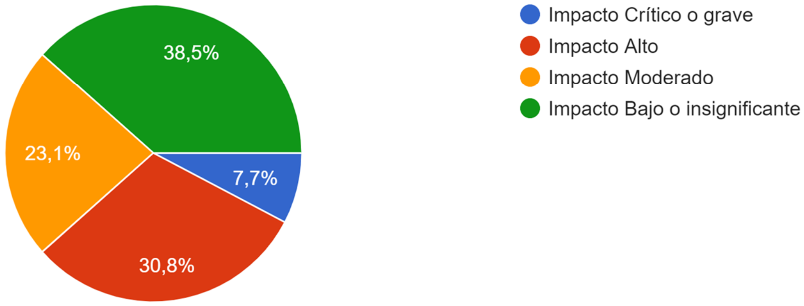
¿Cómo afecta a la operativa actual los episodios de rebase?
11 respuestas



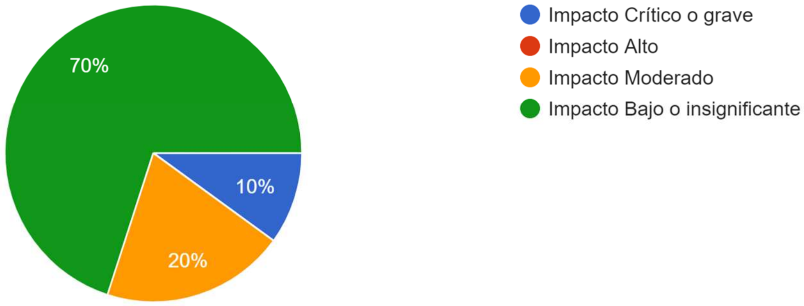
¿Cómo afecta a la operativa actual los episodios debidos a velocidad de viento elevada?
14 respuestas



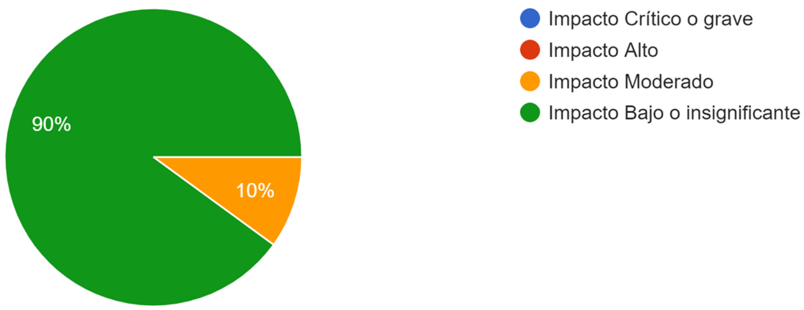
¿Cómo afecta a la operativa actual los episodios debidos a viento proveniente de una dirección especifica?
13 respuestas



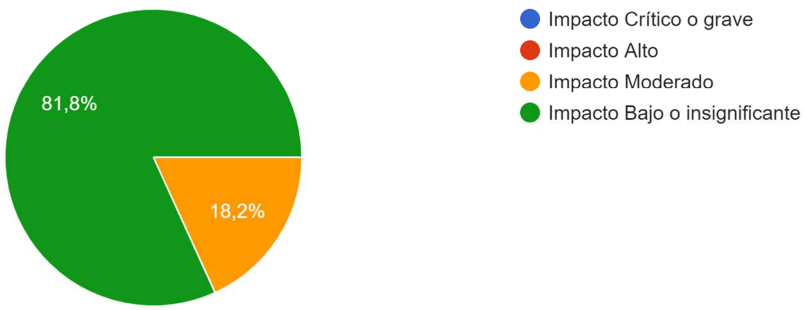
¿Cómo afecta a la operativa actual los episodios debidos a inundaciones?
10 respuestas



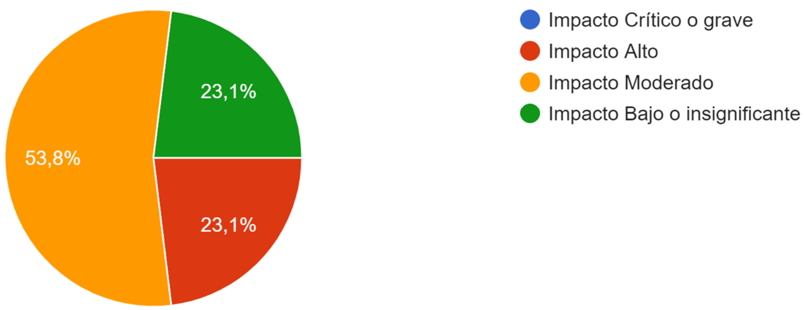
¿Cómo afecta a la operativa actual los episodios debidos a un nivel bajo en la bocana del puerto?
10 respuestas



¿Cómo afecta a la operativa actual los episodios debidos a corrientes elevadas en las proximidades del puerto?
11 respuestas

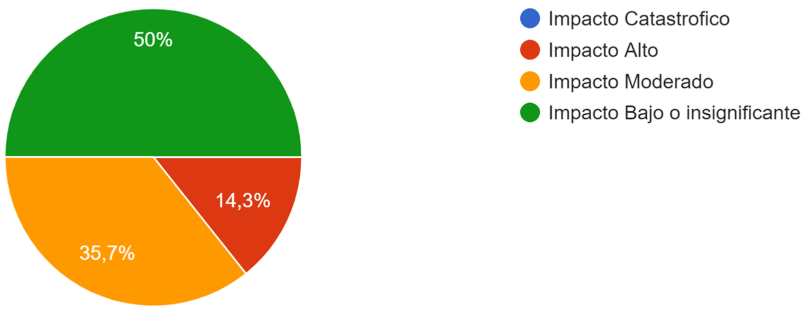


¿Cómo afecta a la operativa actual los episodios de precipitaciones?
13 respuestas

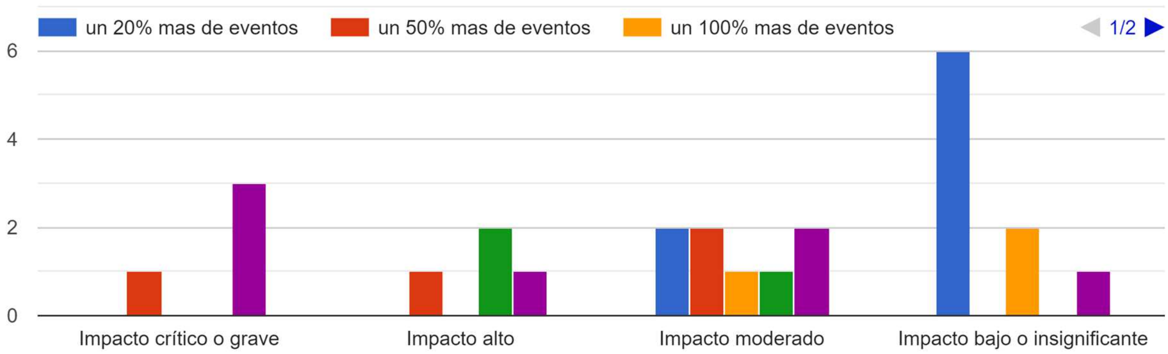


¿Cómo afecta a la operativa actual los episodios debidos a niebla?

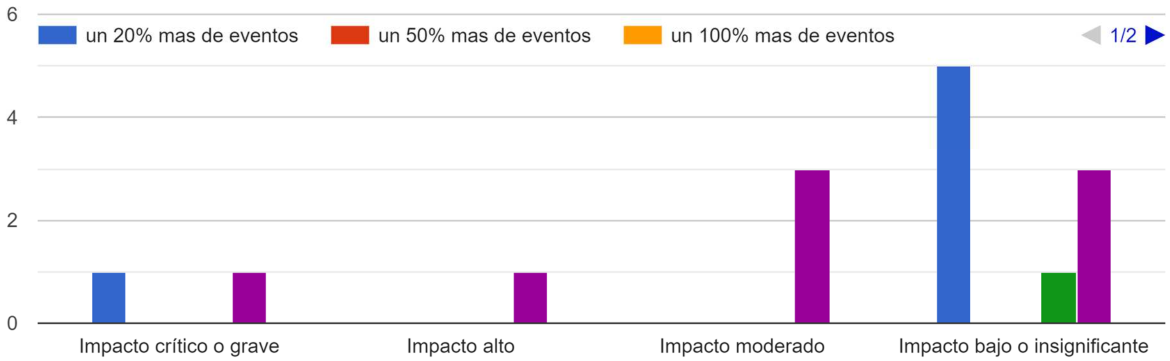
14 respuestas



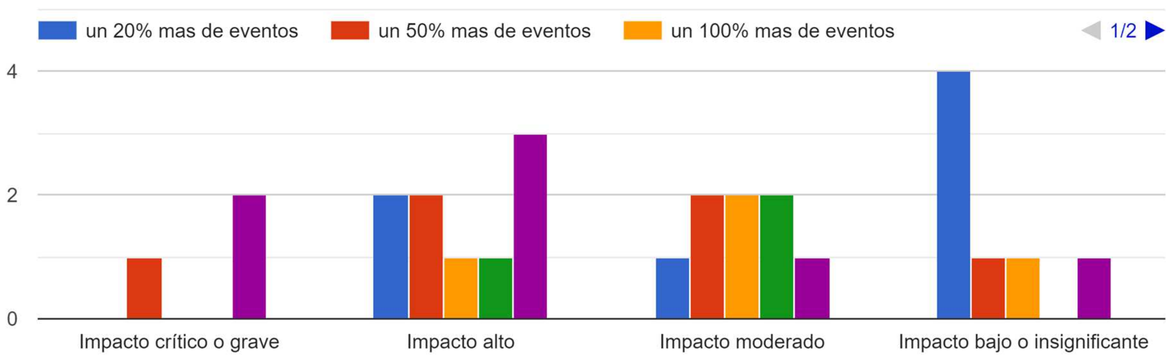
¿Cómo afectaría a la operativa un aumento de episodios de ola de calor?



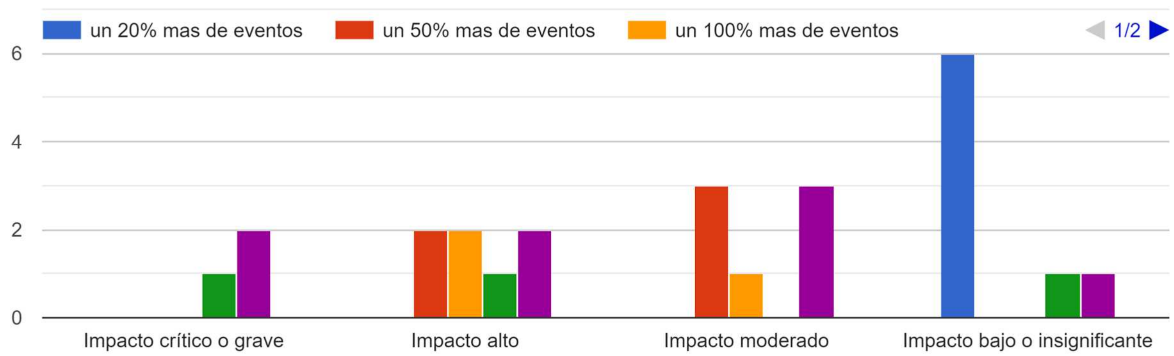
¿Cómo afectaría a la operativa un aumento de episodios de temperatura del agua elevada?



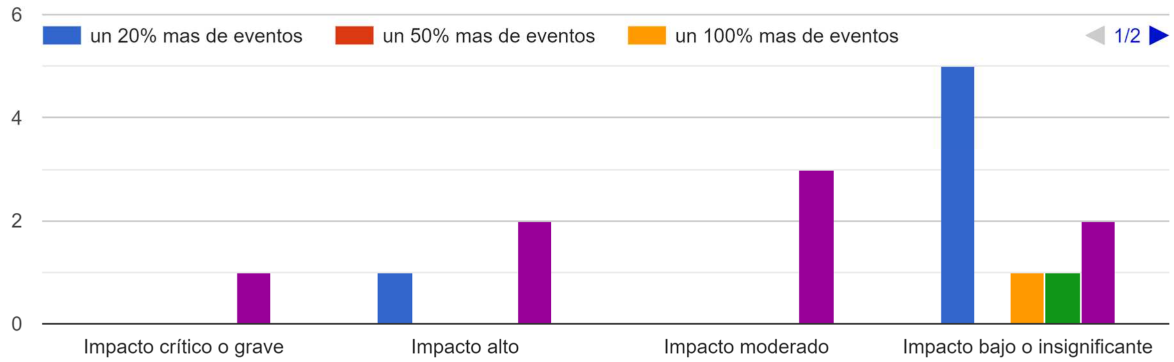
¿Cómo afectaría a la operativa un aumento de episodios debidos a oleaje en el exterior del puerto?



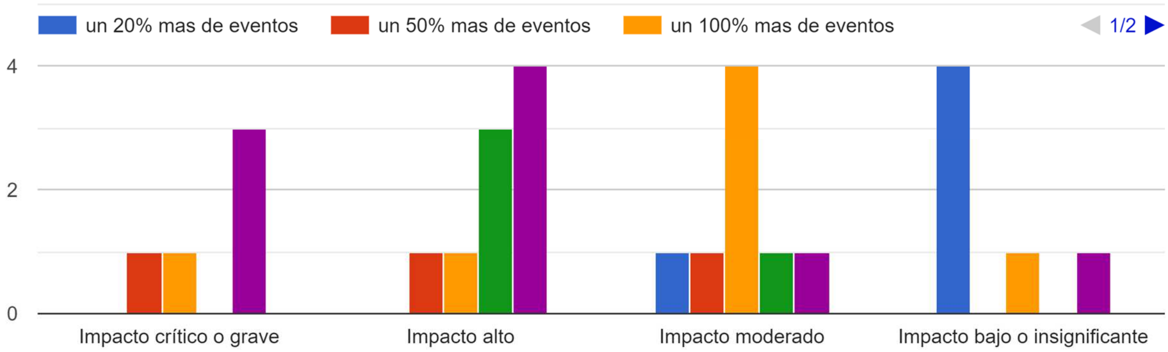
¿Cómo afectaría a la operativa un aumento de episodios de agitación portuaria elevada?



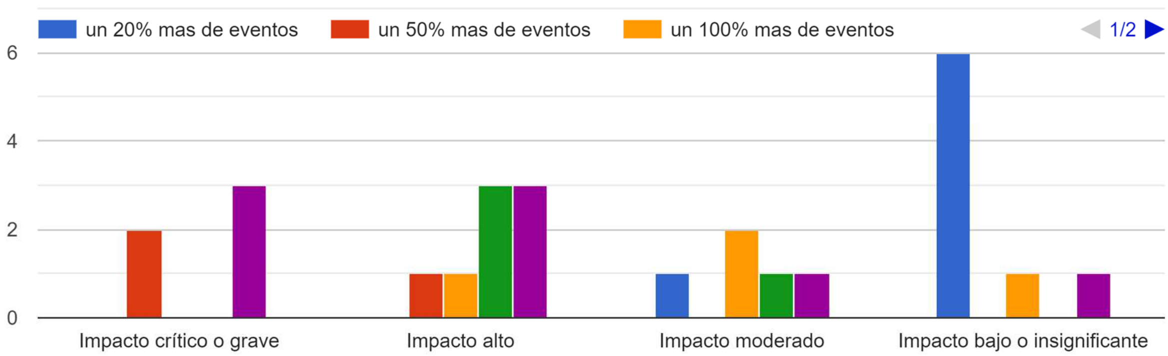
¿Cómo afectaría a la operativa un aumento de episodios de rebase?



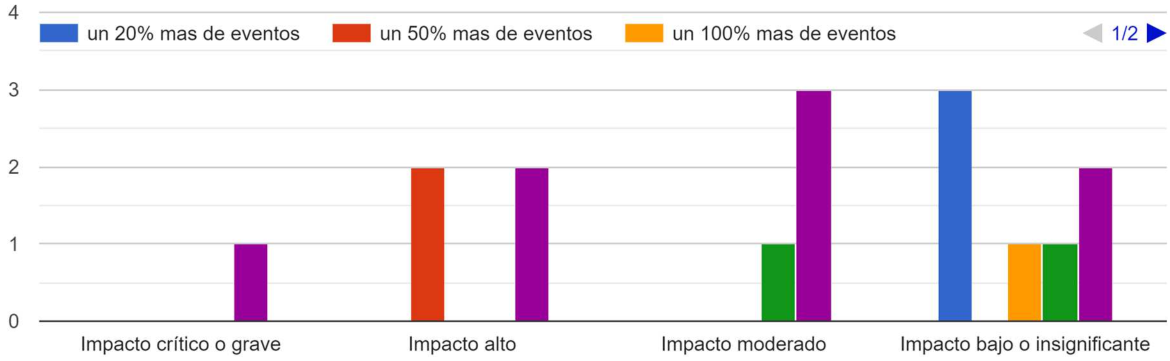
¿Cómo afectaría a la operativa un aumento de episodios de velocidad de viento elevada?



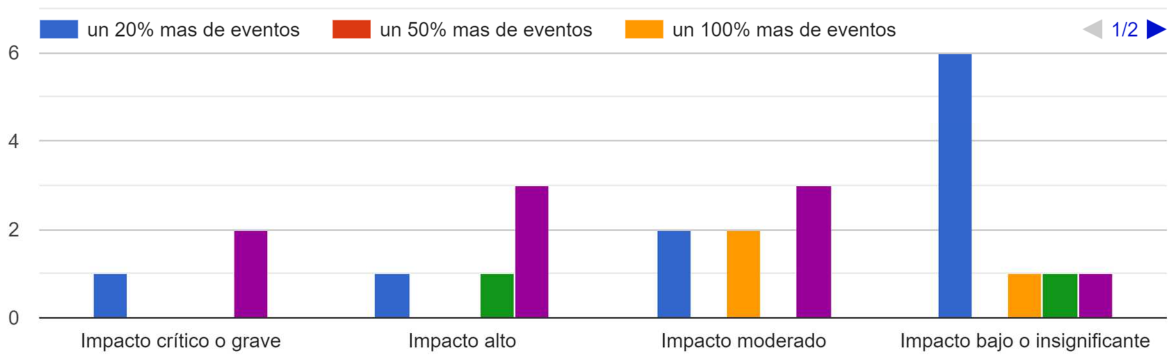
¿Cómo afectaría a la operativa un aumento de episodios asociados a una dirección de viento concreta?



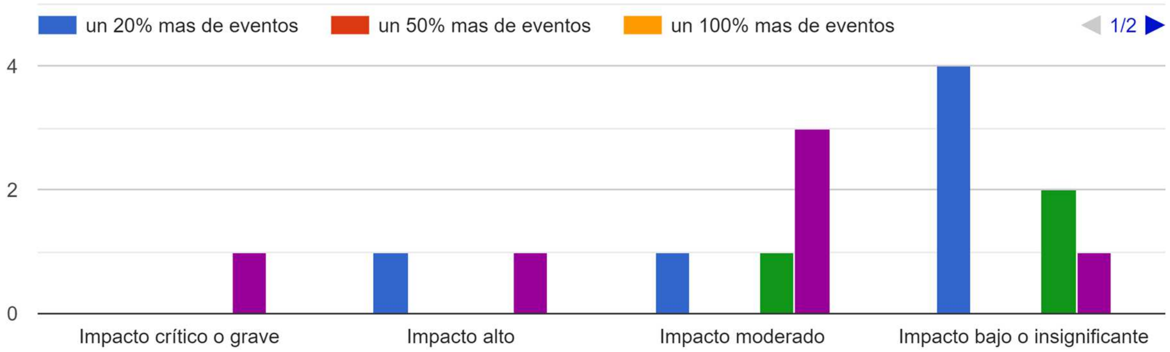
¿Cómo afectaría a la operativa un aumento de episodios asociados a inundaciones?



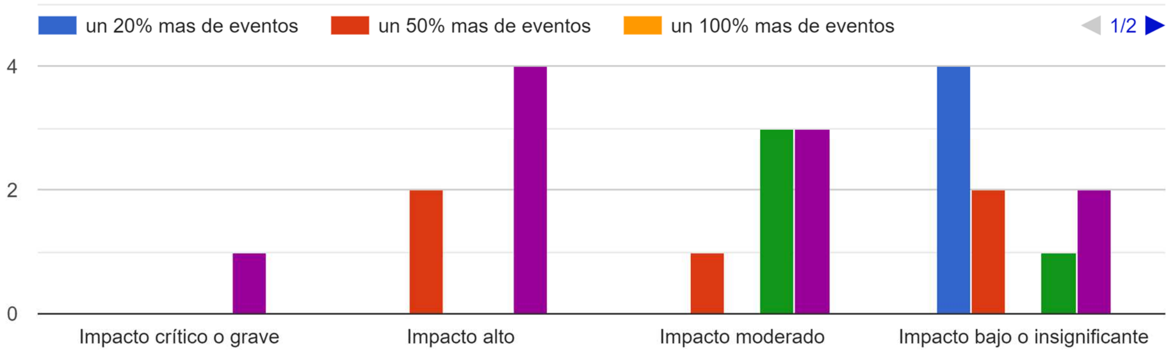
¿Cómo afectaría a la operativa un aumento de episodios asociados a un nivel del mar bajo en la bocana del puerto?



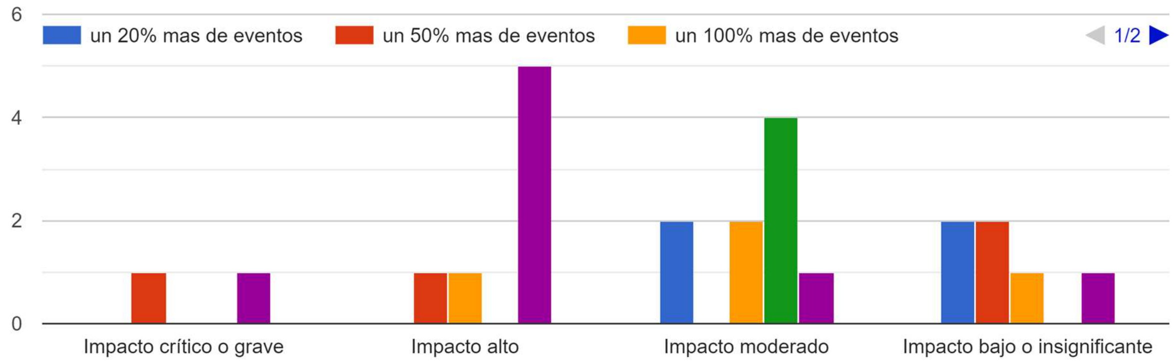
¿Cómo afectaría a la operativa un aumento de episodios asociados a corrientes elevadas?



¿Cómo afectaría a la operativa un aumento de episodios asociados a precipitaciones?



¿Cómo afectaría a la operativa un aumento de episodios asociados a niebla?



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