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SCIENCE FOR A SUSTAINABLE DEVELOPMENT

EVALUATION OF CLIMATE CHANGE IMPACTS AND ADAPTATION RESPONSES FOR MARINE ACTIVITIES

CLIMAR project

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North Sea

FINAL REPORT

EVALUATION OF CLIMATE CHANGE IMPACTS AND ADAPTATION RESPONSES FOR MARINE ACTIVITIES

CLIMAR project

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SUMMARY

Context

Scientific research is needed to assess the impact of climate change, specifically on the vulnerable marine ecosystem and its users. While preventive source measures are necessary, adaptive measures are also needed to cope with the primary and secondary impacts of climate change in the North Sea. Furthermore, instruments are needed that can evaluate the adaptation measures on their sustainability, their impact on marine activities and their relation with preventive measures and sectoral policies.

In the CLIMAR project, a framework was set up, where adaptation measures and strategies can be evaluated for the ecological, social and economic aspects of the Belgian coastal waters.

Primary effects

In the first phase of the research, the primary impacts of the climate changes were assessed.

A literature study on the influence of climate changes on physical parameters showed that the influences are clear, but that still large uncertainties exist in the results of the climate models on the exact local effects. Regional differences can be important. Therefore, it is still difficult to formulate reliable prediction for the climate effects on the Belgian Part of the North Sea (BPNS). A literature study on the influence on the chemical and biological parameters emphasized the complex effects of the climate changes on the ecosystem.

To assess the primary effects on the BPNS, first of all a number of time series of measurements were analysed. Linear regression of the sea level rise at Oostende from 1927 to 2006 showed a sea level rise of 1.69 mm/year, a value higher than the values reported until now. Other regression models show a possible increase in the sea level rise during the last decade(s). Since 1992 a sea level rise of 4.41 mm/year was found. Measurements from the significant wave height from 1978 to 2007 and of the wind speed from 1980 to 2008 were analysed, together with the meteorological wind fields from the Norwegian Meteorological Institute. No clear trend was found in the data. The wind speed at the BPNS shows a small decrease, especially since 1990-1995. This is also found in recent literature, pointing to a decrease in storminess in the southern North Sea. Analysis of measurements of sea water temperature show an increase in sea water temperature varying between 0.023 °C/year in the northern North Sea to 0.053 °C/year in the southern and the central North Sea.

To account for uncertainties in the predictions of the climate changes, climate change scenarios are used. Based on a literature study, on the data analysis and on the climate change scenarios set up in the neighbouring countries, different scenarios were developed for the Belgian situation. These scenarios vary from a moderate scenario, with an expected sea level rise of 60 cm by 2100, to a worst case scenario (WCS) with an expected sea level rise by 2100 of 2 m, and an increase in wind speed of 8 %.

Hydrodynamic, wave and sediment transport models have been applied to estimate the effects of the different climate change scenarios on, *e.g.*, the maximum currents in the vicinity of the harbours, the siltation of the navigation channels and the erosion of beaches. The models show, *e.g.*, that due to the sea level rise, the waves at the Belgian coast could increase significantly.

Identification of secondary impacts

Further, the secondary impacts of the climate changes were assessed, both for the ecological system of the BPNS, and for the socio-economic activities. Three case studies focused on the coastal defence, on the fisheries and on the coastal tourism sector.

An inventory of the different effect categories was established. These effect categories are common for all different sectors, while the effects themselves are specific. The ecological effect categories consist of, amongst others, water quality, changes of habitat and biodiversity. Economic effect categories are the change in production and economic damages. Safety, employment and health are examples of social effect categories.

Using these different effect categories, the specific effects for the coastal defence, fisheries and tourism sectors were listed. Furthermore, the importance of the impacts for the sector were checked and the most important impacts were assessed, using a priority score, taking into account the risks that are already existent, critical thresholds or the time to establish an adaptation plan. Furthermore, the relative importance of the climate change impacts compared to other external impacts, like demographic changes or changes in market prices, was looked at.

For the coastal defence, the most important primary effects are the sea level rise and the possible increase in storminess. Ecological impacts are changes in beach surface area, water quality, changes in habitat and biodiversity, while the damage and victims as a result of flooding are economic impacts. Security, employment or change in attractiveness of the coast are secondary social impacts. For the fisheries sector, the change in sea water temperature, with indirect consequences for the fish stocks, is the most important primary effect of climate changes. Also the change in storminess can influence the sector. Ecological impacts are strongly related and illustrate the complex nature of the ecosystem. Changes in sea water temperature can have effects on all trophic levels, can induce geographical shifts of species, changes in the food chain and so on. Economic impacts are changing production, which is related to changing fish stocks and with the changing number of days at sea. Also for the tourism, an impact table with a complete overview of possible secondary impacts, like loss of beach area, new forms of eco tourism or effects of flooding on touristic values, was set up.

Quantification of secondary impacts

To be able to estimate and evaluate the costs of the adaptation measures, it is necessary not only to identify the secondary impacts, but also to quantify them. However, as a consequence, a good qualitative knowledge of the sector is absolutely necessary. Therefore, the three sectors, which were considered in the current project, were thoroughly described.

For the coastal defence, maps were made of the land use and the infrastructure on the hinterland, which could be flooded. These maps were used for the calculation of the damages and victims during flooding. Also the fisheries sector was described. Only 102 fishing boats remain at the end of 2007, of which 93 % were beam trawlers, mainly fishing plaice and sole. The Belgian fleet is active in different ICES areas, not only in the BPNS, and collect some 22000 ton of fish every year. The analysis showed that external factors, like fuel prices, fish prices and international regulation, like fish quota, are extremely important for the sector. In the description of the sector tourism, a division could be made between the recreational tourism, like beach and water tourism, commercial tourism and other forms of tourism, like culture and wellness.

Since external factors, like demographic evolution and the evolution of fuel prices are important for the quantification of the adaptation measures, it is necessary to make assumptions regarding the evolution of these socio-economic factors for the defined time periods. The uncertainties for these factors is however high, therefore a mean and a maximum scenario were defined, also considering the scenarios of the Milieurapport Vlaanderen and of socio-economic scenarios set up in the neighbouring countries.

The quantification of the secondary impacts was assessed using different indicators, which could be used to estimate the risks and the vulnerability. For each indicator, the indicator was defined and its importance was shown. For the present situation and for the climate scenarios, the changes of these indicators were described. Also, the socio-economic scenarios are taken into account to evaluate the changes of the indicators.

For coastal defence, the reduction in beach area, the damage due to flooding and the victims due to flooding were used as indicators. For the present situation, and for the moderate scenario and the WCS in 2100, the values of the indicators were determined. It was estimated that almost 17% of the beach area in the moderate scenario and 50% of the beach area in the WCS will disappear by 2100 as a result of the sea level rise. The damage and the victims were calculated for an extreme storm with a return period of 1/17000 years, using different models. For the present situation, three weak points in the Belgian coastal defence are identified: Mariakerke, Oostende en Wenduine. The damage, due to an extreme storm is estimated at 0.58 10^9 **€**, the number of victims 10. For the WCS by 2100, breaching is expected for more than 50 % of the profiles, with a total damage of 16 10^9 **€** and 4300 victims.

For the fisheries sector, the change in the distribution and relative densities of the commercial fish stocks is the most important effect of the climate changes. The effect of climate changes is complex, can be direct or indirect and can have effects on different biological levels (individual, population, ecosystem). Furthermore, the effects can be different for the different life cycles, species or regions, and also other factors, like fisheries pressure, can have effects on the final response (e.g., on the changes in growth, mortality, reproduction, population growth and structure).

In the North Sea, the change of distribution as a result of the climate changes are heterogeneous and a combination of different migration patterns, as a shift to deeper waters with about 3.6 m per decade and a shift over latitude.

Also, for tourism the most important risks and their indicators are given. The indicators such as coastal erosion, the presence of sea mammals, the attractiveness of the coast and new commercial activities like eco-tourism, are described.

Development of adaptation measures and adaptation strategies

Adaptation measures can be defined and used to counteract the climate impacts or to use them at our advantage.

Different sorts of adaptation measures were defined. First of all, the population can consider accepting some losses, or can take an insurance for the losses. More proactive, impacts can be prevented. The Flemish Government is drawing up an integrated safety plan to protect the coastal zone against flooding till 2050, while the fishing fleet is being adapted to mitigate or even use the climate change effects. Also regulatory or political measures can be taken to prevent certain climate change impacts. Further, it is clear that climate change can also yield new opportunities. Finally, research and the awareness of the population are important.

For the three case studies, different possible adaptation measures were defined. Furthermore, a pre-Multi Criteria Analysis (MCA) was performed on the different measures, based on different evaluation criteria, like technical feasibility, importance, ecosystem approach, urgency or institutional complexity, to select the most efficient adaptation measures.

For coastal defence, adaptation measures were defined, like the construction of artificial islands, large nourishment schemes or super dikes. The positive and negative effects of these measures were evaluated. The effect of the creation of artificial islands on the coastal erosion is not fully understood, and their construction costly. Super dikes can significantly reduce flooding risks, but require a lot of space to construct. Nourishments are effective and cost-efficient, but require substantial amounts of sand. Finally, controlled flooding of areas, making the population aware of the risk of flooding, or solutions in terms of spatial planning can be considered.

For the fisheries sector, the main measures concentrate on the capture of different species or the use of different fishing techniques. It is clear that the adaptation process must be guided by the government. The international regulations, like fishing quota, will remain very important for the fisheries sector.

For tourism, the adaptation measures with the most potential on success are beach nourishment, weather forecasting tools, road pricing and preparedness for marinas.

For the development of adaptation measures and strategies, the public participation of the different stakeholders is very important. In the framework of the CLIMAR project, three workshops were organised on the development of adaptation strategies for the coastal defence, the fisheries and the tourism sector.

To deal with a certain risk in an integrated manner, the different adaptation measures were combined together in adaptation strategies. In the CLIMAR project, four different adaptation strategies were considered: a "Business-As-Usual" strategy, an adaptive approach, a more intense adaptive approach and a reactive approach. For the coastal defence, large scale beach nourishment is considered to be part of an adaptive approach, while the installation of super dikes is part of a reactive adaptation strategy.

Evaluation of adaptation strategies

The final goal of the CLIMAR project was the development of a tool to evaluate and compare the different adaptation strategies. Since different combinations of climate change scenarios, time scales, socio-economic scenarios and adaptation strategies are possible, different comparisons were executed in the project. For instance, the business-as-usual approach, together with the moderate climate change scenario and with the mean socio-economic scenario, were compared to the adaptive and the adaptive+ approach, with the same climate change and socio-economic scenarios for 2040.

The tool to evaluate the different scenarios is based on a Multi Criterion Analysis (MCA) and a Cost Benefits Analysis (CBA). After selection of the adaptation strategies, the ecological and socio-economic indicators are quantified. The avoided risk for the selected adaptation measure are calculated, together with the related costs. This serves as input for the MCA analysis, both on monetary as well as on semi-quantitative scale. After the attribution of different weights for the effects, the score of the adaptation strategy is calculated and a ranking of the different adaptation strategies is established. To deal with the uncertainties involved in the quantification of the indicators and in the weighting of the effects, a sensitivity analysis is executed on the basis of alternative weighting criteria and an uncertainty analysis is executed, using a Monte Carlo technique, to look at the effects on the ranking.

The tool was applied as an example for the tourist sector. The adaptive+ approach, with a full set of adaptation measures in addition to beach nourishment and on-line weather forecasting, *e.g.*, tourist climate change contribution and road pricing, proved to be the best approach. The sensitivity analysis didn't show very large variations. For the coastal defence the best solution to maintain safety against flooding under sea level rise was shown to be strengthening the existing coastal defence line, namely heightening and/or widening the beaches, dikes and dunes. It was also shown that the installation of artificial islands is not an equally efficient solution.

For optimising coastal flood risk management it is suggested to perform further research into non-structural measures, such as specific contingency plans for coastal flooding events and the strengthening of buildings so they remain structurally stable under the hydraulic impact of overtopping waves, and into quantifying intangible losses from flooding, such as health, environmental and cultural heritage-related effects.

For the fisheries case-study it proved to be very difficult to follow the methodology for the development of an evaluation tool for adaptation strategies. The complexity and uncertainties encountered on each preceding step made it difficult to develop a realistic evaluation tool. Many assumptions were made and reality was oversimplified. Therefore the current tool should be considered as basis of which several components can be further elaborated. . Although the large uncertainties in the results, which should be treated with caution, the results do indicate the importance of considering adaptive strategies now, in order to solve the adaptation issues, both from an economic as from a sustainable point of view.

Finally, it is important to realise that the implication of different adaptation measures could have political and legal constraints. The policy and legal evaluation of adaptation measures has shown that although for most measures a legal framework is in place, some legal amendments are needed to provide an adequate tool to support adaptation measures. For instance, Belgian insurance law need to be amended in order to provide for an adequate risk pricing insurance linked to flood zone hazard maps and climate proof building standards, eventually leading to higher premiums for high risk zones. In addition current initiatives, such as the development of different emergency and intervention plans and the contingency planning for the North Sea need to take into account risks of climate change in order to be able to fully respond as an adequate adaptation measure. For other adaptation measures implementation is highly connected with developments that take place at European level.

Furthermore the study on mainstreaming climate change adaptation into existing legislation has stressed the benefits of including climate change adaptation into existing Strategic Environmental Assessment (SEA) legislation. This guarantees that SEA becomes a useful tool to facilitate decision-making in the light of climate change effects. SEA addresses problems and promotes actions on adaptation to climate change in the planning process, and highlights possible adaptation conflicts with other existing regional/national plans and programmes.

Keywords: climate change, primary impacts, adaptation measures, adaptation strategies, evaluation tool, coastal defence, fisheries sector, coastal tourism, legal aspects

1 INTRODUCTION

1.1 CONTEXT

Based on the recommendations of the "Intergovernmental Panel on Climate Change" (IPCC), the Kyoto-Protocol and relevant national strategic documents, scientific research is needed to assess the impact of climate change, specifically on the vulnerable marine ecosystem and its users. While preventive source measures such as cutting greenhouse gas emissions are necessary to tackle the problem at long term, adaptive measures are necessary to cope with the primary and secondary impacts of climate change in the North Sea. Furthermore, instruments are needed to evaluate the adaptation measures on their sustainability, their impact on marine activities and their relation with preventive measures and sectoral policies.

The North Sea plays an important role in our country's cultural, social, and economic well-being. The North Sea Ecosystem is characterized by high productivity and highly diversified habitats but also by heavy ship traffic, intensive fishery, a number of offshore activities such as oil and gas extraction, the presence of cables and pipelines, sand and gravel extraction, dredging activities, and energy production by offshore wind farms. This intensive use has as a consequence that the vulnerability of the ecological, social and economic community formed by the North Sea is high (in terms of risk on damage) for climate change. This calls for a sustainable approach when addressing climate change issues in our North Sea.

The effects of climate change on marine systems are manifold. Sea level rise is an important indicator of climate change in coastal regions. It increases the likelihood of storm surges, coastal erosion, landwater salt intrusion, endangers coastal ecosystems, etc. Changes in the sediment transport cycles will occur and cause, together with the changing hydrodynamic conditions, secondary effects, *e.g.*, on dredging activities, marine transport and harbour activities. Ocean warming can increase zoo- and phytoplankton productivity (CO_2-uptake), increase risks for human health, change the marine species composition, stress the fishery activities, etc.

It is obvious that the marine ecosystem has a certain autonomous adaptation capacity to counter these effects. On the other hand, some secondary effects will have synergetic or contradictory results. Adaptive scenarios developed by an individual sector could influence another parts or users of the marine environment.

1.2 OBJECTIVES AND OUTCOMES

The objective of CLIMAR is the elaboration of an evaluation framework for adaptation scenarios/measures as a response to climate induced ecological, social and economical impacts and this for the Belgian North Sea environment.

The objectives can be synthesized as follows:

- Definition and modelling of climate change induced primary impacts at North Sea scale: sea level rise, increased storminess, possible increased rainfall, temperature, etc.
- Deduction of climate change induced secondary impacts for both the marine ecosystem in general and for related socio-economic activities with the focus on three case studies (sectors): coastal flooding, fisheries and coastal tourism.
- Identification of adaptation scenarios/measures for the three case-studies and using these for extrapolation towards the marine ecosystem in general and to related socio-economic activities.
- Development of an evaluation framework, based on the three case studies, to assess the effectiveness of the identified adaptation scenarios/measures for each specific marine activity.
- Evaluation of the effects of the proposed adaptive strategies, focusing on the embedding of these strategies in the global climate change policy, their practical integration in the current policy and legislative framework and possible implementation problems.
- Formulation of recommendations towards North Sea future policy and its different socio-economical activities. Based on the three case studies, coastal flooding, fisheries and coastal tourism, on the one hand and the parallel integrated assessment and policy and legal evaluation on the other hand, recommendations are formulated for North Sea future policy and its different socio-economic activities.

It is clear that this project provides a valuable output for climate change policy for the North Sea. This output consist both of practical tools (modelling, assessment) as well as (semi)quantified results and applications.

2 METHODOLOGY AND RESULTS

2.1 METHODOLOGY

CLIMAR aims to determine and evaluate in detail the effects of climate change and possible adaptation scenarios in the North Sea, both on a regional (Belgian Part of the North Sea - BPNS) and sectoral scale:

- Regional scale: some strategies will be relevant for several sectors or for the North Sea environment as a whole.
- Sectoral scale: following coastal and marine sectors have been selected to examine the climate effects in more detail: coastal infrastructure (case study), fisheries (case study) and coastal tourism (additional sector used as basis for the development of the methodological framework).

In general, 4 steps can be distinguished in the adaptation process to climate change:

1. Scoping the impacts;
2. Quantifying the risks;
3. Decision making and action planning;
4. Adaptation strategy review.

2.1.1 Scoping of the impacts

In a first step the main impacts of climate change that are expected for the Belgian Part of the North Sea are identified, as well as the translation of these impacts towards the different marine sectors. This has been translated in the following work packages (WP).

2.1.1.1 Definition and modelling of climate change induced primary impacts at the North Sea scale – Identification (WP1)

A first step in CLIMAR has been to differentiate the primary impacts of climate change from the natural evolution at the North Sea scale:

- Hydraulic impacts: determination of sea level rise, change of storminess, change in hydrodynamic climate (flooding).
- Physical and chemical changes: change of temperature, salinity, nutrients and phaeocystis.
- Impacts on erosion and sedimentation: change of erosion and deposition patterns (*e.g.*, siltation).

2.1.1.2 Deduction of secondary impacts both on the marine ecosystem as well as on other socio-economic activities – Identification (WP2)

Secondary impacts as defined in the proposal are those derived from primary impacts. Secondary impacts of climate change have been deduced at the regional, as well as at the sectoral scale:

- Regional: Based on a study of primary impacts assessment, secondary impacts on the marine environment are identified for the Belgian coastal and marine waters.

A global literature study has been conducted to identify all secondary impacts. They were classified according to their ecological, social and economical nature.

- Sectoral: Climate change will affect different sectors in a different way. On the other hand, within a specific sector, differences can be observed depending on the activity considered. One sector can thus be divided into several subsectors (only when relevant). Secondary impacts (ecological, economic and social) have then been worked out in more detail per subsector.

2.1.2 Quantifying risks

In this step the magnitude of the primary impacts and the impacts on a sector have been examined in more detail. This is important to decide on adaptation strategies for the North Sea ecosystem. Compared to "Scoping the impacts", here a quantitative completion occurs.

To be able to do this a good insight in the sector is necessary. Each sector (and its subsectors) has therefore been described in a separate subdocument including definitions, intensities and geographical location, socio-economic importance and important external factors.

In addition, some socio-economic factors (external factors) (e.g., demography, ageing population, employment) have been identified to be incorporated into the quantification step if a more realistic outcome is intended.

2.1.2.1 Definition and modelling of climate change induced primary impacts at the North Sea scale – Quantification (WP1)

2.1.2.1.1 Quantifying the primary impacts

To establish these primary impacts, three different methodologies have been used in the project: literature study, statistical analysis of time series and numerical modelling.

It is clear that global climate change is an extremely complex matter, involving many different aspects and disciplines. The IPCC has published in the course of 2007 the '4th Assessment Report' (IPCC, 2007), which discusses in length the different effects which could be expected. Many different publications can be found in the literature on the subject. Although there is general agreement on the fact that effects are to be expected, the uncertainties remain, however, very high. Furthermore, the regional differences can be significant.

A method to determine the primary impacts of the climate changes is statistical analysis of time series. Data series of sea level, waves and wind speeds and wind directions have been used to determine the sea level rise and the changes in storminess for the Belgian coastal waters. Different statistical models (linear trend, accelerated trend,...) have been used to fit the data and to get more insight in the observed changes. Data series of sea water temperatures have been analysed to get information on the increase of the sea water temperature, a parameter of importance, e.g., for the fisheries.

Besides numerical models have been used to evaluate the impact of climate change scenarios (see 2.1.2.1.2) on hydrodynamic and morphodynamic parameters.

The hydrodynamic model OPTOS-BCZ is used to evaluate the expected sea level rise and increase in wind speed, as defined in the different climate scenarios, on different parameters, as mean and maximum depth averaged currents, mean and maximum bottom stress and tidal amplitude. The second generation wave model mu-WAVE is used to evaluate the impact on the mean and maximum significant wave height under the influence of the sea level rise and change in wind speed. The wave model SWAN, implemented for the Belgian coast, is used to evaluate the changes in the wave propagation in the shallow Belgian waters under different sea level rises, defined in the climate scenarios.

Finally, the sediment transport model mu-STM, is used to evaluate the impact of the changes in sea level rise and wind speed on the siltation of the fair channels and sea harbours.

2.1.2.1.2 Climate change scenarios

As there remains many uncertainties about how much climate change will happen, a range of climate change scenarios have been developed. Both mid (2040)- and long (2100)-term scenarios have been drawn based on both comparable literature studies of neighbouring North Sea countries and on the modelling results for the Belgian Part of the North Sea.

2.1.2.2 Deduction of secondary impacts both on the marine ecosystem as well as on other socio-economic activities – Quantification (WP2)

2.1.2.2.1 Quantifying the secondary impacts

The secondary impacts (direct and indirect) have primarily been quantified in more detail for two sectors (case-studies): coastal infrastructure and fisheries. With its close connection to the environment and climate itself, tourism has been considered as a third climate-sensitive economic sector for the BPNS.

For the quantification of the secondary impacts an indicator approach has been chosen. An indicator is a variable or measure describing a "key-element" (here the main ecological/ social/ economic effects) of the system. The indicator takes into account both the element at risk (*e.g.*, number of tourists) and their vulnerability (*e.g.*, mobility, protection status by existing adaptation measures, etc.). Indicators have been worked out for the most significant climate risks (high priority score).

Based on the climate change scenarios and taking into account the socio-economic scenarios, the impacts were quantified according to the methodology presented in Figure 1.

Coastal flooding

In the case study of coastal infrastructure, the most important primary impacts of climate change are sea-level rise and increased storminess (increase in frequency of storms, higher storm surges and increase of wave height during storms).

The direct consequences of these physical phenomena are events like flooding and increase in coastal erosion. In combination with increasing human settlement and infrastructure developments in the coastal zone, considerable ecologic, economic and social consequences can be expected.

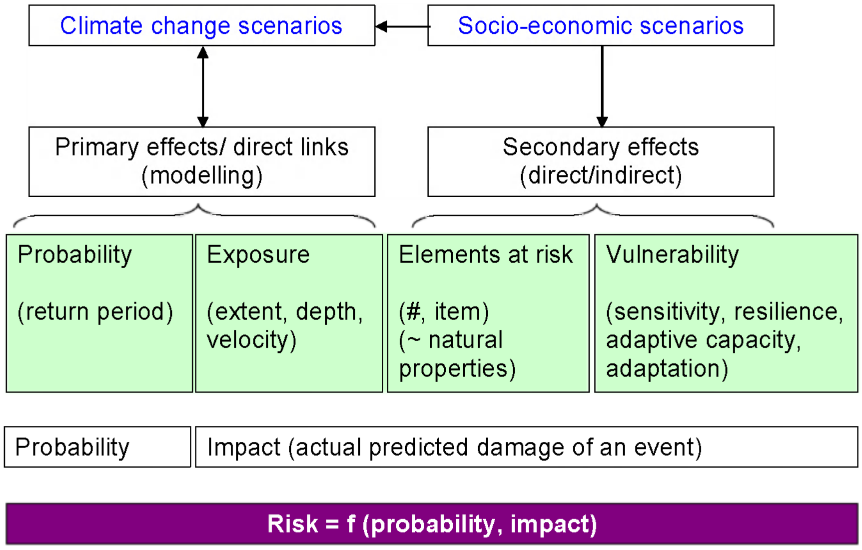


Figure 1: Quantification of climate impacts

The effect of storms for different scenarios of climate change on the present-day coastal infrastructure and on the coastal plain can be simulated, using flood risk calculations. The first tool in flood risk calculations is the modelling of the erosion on beach and dune, using the DUROSTA model, to identify at which locations alongside the Belgian coastline a failure of the water fronted defence structure (formation of a breach) can be expected. The next tools used in flood risk assessment are hydraulic flood calculations, to estimate the area susceptible to flooding, due to overflow or breach formation. Flood calculations have been carried out using the numerical model MikeFlood. The risk calculation methodology is described in Van der Biest et al. (2009a). Further, also the effect of the sea level rise during the climate change scenarios for 2040 and 2100 on the beach surface area has been assessed.

The present state of these risk indicators and the expected evolution under a 'do-nothing' scenario have been quantified for the moderate and the worst case climate change scenario for 2040 and 2100. This quantification will serve as a reference situation to evaluate the possible benefits of implementing the adaptation strategies in WP4.

Fisheries

The secondary effects identified under the ecological effect categories are strongly linked and reflect the complexity of the ecosystem. The literature study dealing with the impacts of climate change on the ecological parameters already indicate that all trophic levels of the food web are affected by climate change.

The status of the fish stock, which forms a component of the ecosystem considered, is therefore associated with the whole ecosystem and the changes it is undergoing due to climate change. The effect of climate change on fish stocks is very complex and sufficient long-term data sets, suitable models, specific expertise and ample time are indispensable to perform the analyses needed to predict effects of climate change on fish stocks. Within the framework of CLIMAR it was opted to base the identification and quantification of the secondary impacts relevant for Belgian fisheries on a literature study and modelling work currently undertaken by several (ICES) scientists and working groups. As many studies consider temperature as the most important factor in relation to fish stocks, the status of the (potential) commercial fish stocks and the effect of (future) water temperature rise have been considered for quantification.

The effect of increased storminess and bad weather conditions were identified as these primary effects directly impact the functioning of the fleet and the safety onboard of the crew. However a literature review shows that the change in the frequency of severe storms for the areas fished by Belgian vessels is ambiguous.

Coastal tourism

The quantification of the secondary impacts for coastal tourism has mainly been based on available literature including indicator studies on tourism, sector reports, and expert interviews. The impacts on coastal tourism are highly linked with the effects determined in the case study coastal flooding. Based on the model results the flood risk area has been determined affecting also coastal tourism (e.g., beach area at risk).

2.1.3 Decision making and action planning (adaptation)

Adaptation means to take action either to reduce the chance of a hazardous event happening, or to reduce the magnitude of its consequences. A difference can be made between autonomous adaptation (actions taken naturally by private actors) and policy-driven adaptation (result of deliberate policy decisions).

2.1.3.1 Identification of adaptation measures

A first step has been the identification of all possible adaptation measures (both structural and non-structural) as a response to the secondary impacts. Adaptive measures have been worked out per sector and specific linkage has been made to secondary and primary impacts. Initially the focus has been on actions to manage the priority risks identified through the earlier steps. These risks have therefore been subjected to questions like 'How do these risks compare to non-climate risks? Do I need to adapt to this climate risk? And at what cost?'.

The identification of alternative adaptation measures has benefit from the partnership of CLIMAR as a discussion platform was created. The same is true for the interactive workshops organised per sector (public participation).

The identified adaptation measures have then been subjected to a Multi Criteria Analysis (MCA) in order to select the most efficient measures (ranking) as starting point for the adaptation strategy.

The MCA performed in this pre-assessment phase should be seen as a first screening (brief and quick) of an extended list of possible adaptation measures to come (on an efficient way) to a list with the most promising measures that can be further evaluated (see WP4).

The MCA has been based on a number of important characteristics of the adaptation measures like effect (risk reduction), technical feasibility, multi-sectoral character of the measure, urgency of implementation, no-regret options, etc. These criteria are the result of a literature study of existing analysis tools, expert knowledge and public participation (sector).

2.1.3.2 Identification of adaptive strategies

Finally, the measures have been combined as sectoral adaptive strategies. A climate adaptation strategy represents a combination of measures and options chosen to meet a particular risk (European Environment Agency, 2004). The strategy should increase the robustness of long term (infrastructure) investments, enhance the adaptability of vulnerable natural systems, improve societal awareness and preparedness, increase the flexibility of vulnerable marine activities (*e.g.*, ease of change of activities or locations). The success of the full strategy depends on numerous factors such as the effectiveness of the measures, the acceptance of the introduction, the potential for benefits that outweigh the costs, the consistency of the measures with other sectoral initiatives, etc.

These strategies or combination of adaptive measures serve as the base for evaluation. They have not only been based on literature review but have been confronted with sectoral opinions by means of interviews and/or workshops.

2.1.4 Adaptation strategy review

2.1.4.1 Evaluation of adaptation strategies

In order to stimulate the above mentioned preconditions for the sectoral adaptation strategies, an evaluation framework has been developed that can assess the value of the scenarios for each specific marine sector. The evaluation tool (multi criteria analysis – MCA / cost benefit analysis - CBA) is based on the principles of sustainable development and scores both economical, ecological and social merits and damages of the adaptation strategy. Hence the adaptation strategies have to undergo a sustainability test. Full use will be made of the case-studies for coastal flooding and for the fisheries sector, as well as, from a methodological point of view, the elaboration of an assessment framework during the ADAPT project (Giron et al., 2008). Besides the climate change evolution, the decision framework will also consider the parallel socio-economic evolution (*e.g.*, demographics, policy and juridical evolutions, economic changes) in order to increase the policy relevance. For that reason, an intermediate time-step (year 2040) was introduced during the first phase of the project.

2.1.4.2 Policy and legal evaluation of adaptive strategies

The legal approach for this research is twofold. On the one hand, there is the evaluation of adaptation measures and on the other hand, there is the evaluation of adaptive strategies.

In order to evaluate the proposed adaptation measures and adaptive strategies, a list of relevant policy decisions and legislation was made. Nowadays environmental legislation is to a large extent determined by international and European (soft and hard) law, in Belgium transposed and implemented at the regional level, although the federal government retains important prerogatives. Furthermore adaptation measures anticipating climate change effects are rarely "stand-alone" environmental measures and therefore the involvement of several other laws and policy sectors at different levels is required. Relevant international, European and national legislation will ensure that a legal framework can be established for the proposed adaptation measures. In addition the institutional complexity for each adaptation measure was determined. From a policy perspective the implementation of adaptation measures for coastal regions implies decision-making in a complex situation, often with conflicting interests, especially in the Belgian coastal zone, which is a multifunctional area with a wide range of activities (tourism, dredging activities, sand and gravel extraction, shipping and fishing activities, ...) and stakeholders involved. Various (sectoral) legislative acts and decisions are promulgated to cope with these activities. Due to the division of competences, a large number of governmental departments and policy bodies (public works and mobility, spatial planning, environment policy, nature conservation policy, water policy, tourism and recreation policy) are involved. Elements of institutional complexity are:

- Clashes between institutional rules
- The organizational consequences of certain options taken
- The cooperative relations or associations which are necessary for implementing the adaptation measure

Departing from international and national climate change policy and its legislative framework, the adaptive strategies against secondary climate change impacts were evaluated. It was investigated to what extent use can be made of existing policies and tools such as Integrated Coastal Zone Management (ICZM) and Strategic Environmental Assessment (SEA).

2.1.5 Recommendations

Based on both case studies on the one hand and the parallel integrated assessment and policy and legal evaluation on the other hand, recommendations are formulated on the effect of the adaptive strategy, the embedding in the global climate change policy as well as the practical integration of this strategy in the current policy and legislative framework.

It is clear that this project provides a valuable output for climate change policy for the Belgian Part of the North Sea. This output consists both of practical tools (modelling, assessment) as well as (semi)quantified results and applications.

2.2 PRIMARY IMPACTS

2.2.1 Definition and modelling of climate change induced primary impacts at the North Sea scale – Identification

The primary impacts of climate change mainly concerns temperature, sea level, storminess and ocean circulation patterns. Climate change will also have an indirect impact on the flooding due to sea level rise as well as to storm surges, and to coastal erosion. Furthermore, it will also affect chemical parameters of the North Sea by a modification of its carbon budget that will result in an acidification of the sea water.

2.2.2 Definition and modelling of climate change induced primary impacts at the North Sea scale – Quantification

Three different methodologies have been used to quantify these impacts for the Belgian Part of the North Sea: literature study, statistical analysis of measurements and numerical modelling.

2.2.2.1 Literature study on physical and chemical parameters

Coupled atmosphere-ocean general circulation models are used to produce climate projections for centuries, and to simulate the response of several climate variables to different scenarios for greenhouse gases emissions. However, they are designed to resolve phenomena of several hundred kilometres, and are no more reliable below this scale. As a result, regional coastal systems are not resolved sufficiently in these models. Downscaling techniques, based on statistical relationships between global and regional parameters are therefore required to resolve climate change for regional systems. However, clear relations between local key processes and large scale climate variability are difficult to obtain. Further problems occur because a changing climate may cause changes in the statistical relationship between global and local parameters. The assessment of local impacts is therefore very difficult. A way of dealing with the uncertainties is to draw a series of plausible climate change scenarios.

The primary impacts of climate change mainly concerns temperature, sea level, storminess and ocean circulation patterns. Climate change will also have an indirect impact on the flooding due to sea level rise as well as to storm surges, and to coastal erosion.

For the period 1978-2002, there has been an increase in the sea surface temperature of the North Atlantic of 0.3 - 1 °C, however small areas show a cooling trend. The annual mean wind speed averaged over the North Sea seems to be increased by 10 % between 1960 and 2000. Analyses of past climatic conditions in the North Sea show anomalies in the wind forcing for the past decades: increases in wind strength as well as changes in its direction. The potential impacts of sea level rise are great and unevenly distributed across the globe. Low level “hot spots” in Europe included the Belgian coast, which in significantly threatened, even for a 2 m increase in sea level.

In Ponsar et al. (2007), more information on this literature study is presented, summarising the actual knowledge on the changes of hydraulic and physical parameters in the southern North Sea, as an effect of climate changes.

2.2.2.2 Literature study on ecological parameters

The most productive areas in the oceans are the shallow continental shelves (water depth less than 200 meters). They make up for less than 7 % of the ocean's surface but the greatest proportion of primary and secondary production takes place there and they are the most productive fishing grounds. They are also the areas the most intensely affected by the impacts of climate change. Moreover, coastal systems play a critical role in protecting the coasts from flooding and erosion (Schubert et al., 2006).

The response of marine ecosystems to climate change is dependent of many intricate factors. In addition to natural spatial and temporal variability in the effects of climate change, other factors such as fishing and physical oceanographic factors affect the abundance and distribution of species. The difficulty in identifying the cause of these effects is complicated by buffering (many fish, marine mammals, seabirds and some benthos are long lived and therefore the effects of oceanographic conditions may be buffered at the population scale and integrated over time) and by complex life histories (with eggs, larvae, juveniles and adults often in different places both geographically and in the water column). Moreover, the abundance and distribution of species is affected by other factors such as eutrophication, pollution, diseases and introduced species. The ecological responses to climate change may be partially or wholly hidden by other factors such as fishing pressure and habitat alteration.

In addition to the specific characteristics of a region, the response of marine systems to climate changes depend on other human induced changes in the marine environment; for example, fishing has reduced the number of large fish at high trophic levels whilst increasing agricultural and household activities have resulted in nutrient enrichment of many coastal waters (Philippart et al., 2007).

Causal attribution of recent biological trends to climate change is thus complicated because external factors (non climatic influences) dominate local, short term biological changes.

The increase in surface ocean CO_2 has consequences for the chemical equilibrium of the ocean which is becoming more acidic. It has also impacts on marine organisms using carbonate to produce shells consisting of calcium carbonate $CaCO_3$.

Climate change is predicted to have direct and indirect effects on marine plants and animals and consequently on marine food webs. Firstly, changes in temperature will directly affect metabolic and developmental rate in many animals, and processes such as photosynthesis and respiration in plants. Secondly, changes in mean annual temperature will affect change in isotherms and consequently in the distribution of marine organisms. Thirdly, alteration of life cycle events that are triggered by environmental clues related to climate may lead to decoupling of trophic interactions.

Fourthly, species with short generation times and rapid population growth rates might be able to adapt to new environment as the result of evolutionary change.

The ecological changes that have occurred in the North Sea in the late 1980s and 1990s are sufficiently abrupt and persistent to be termed "regime shift". This regime shift has a profound impact on the North Sea ecosystems. These impacts range from step-wise changes in nutrient ratios and pronounced changes in the abundance, composition and distribution of plankton. There are ample evidences of shifts in biogeographical distribution and abundance at different trophic levels: in phytoplankton, zooplankton, benthos, and fish species. For example, a northward shift in Atlantic cod is reported, while densities in monkfish remained constant. The population in haddock decreased in density in the southern part of the North Sea but increased in the northern part. Evidences of correlations of distribution of seabirds with sea temperature are also reported for the Atlantic puffin, the black legged kittiwake and the northern fulmar.

Over the last decades, changes of phytoplankton species in the northeast Atlantic have created anomalous phytoplankton blooms with harmful consequences on humans and on the surrounding ecosystem. Toxic material released from these blooms are causing mass mortalities of marine organisms, as well as affecting human health through contaminated shellfish and fish populations. Global climate change expressed as an increase of the summer temperature maximum by 4 °C in 2100, in combination with water column stratification, led to a doubling of growth rates of potentially harmful algal blooms. However, the wide ranges of uncertainties in the projected increases in temperature and precipitation associated with climate change, and the impossibility to take into account the effects of temperature and stratification changes on ecological processes that are important in phytoplankton species prevents a quantitative assessment of the risk of harmful blooms.

More information on this literature study can be found in Ponsar et al. (2008).

2.2.2.3 Data analysis

A second method to determine the primary impacts of the climate changes is statistical analysis of time series. First a trend analysis of the mean sea level was performed. Further an analysis of wave measurements and wind measurements on the BPNS was used, to get some information on the changes on the storminess. At last measurements of the sea surface temperature on the entire North Sea were analysed.

2.2.2.3.1 Trend analysis of relative mean sea level at Oostende

The goal was to get the longest times series possible for different parameters at the BPNS. The hourly water levels of the sea level at Oostende for the period 1980-2006 and the high and low waters at Oostende for the period 1925-1979 were received from the Agentschap Maritieme Dienstverlening en Kust (MDK), Afdeling Kust. Furthermore, monthly and yearly mean water elevations at Oostende were downloaded from the server of the Permanent Service for Mean Sea Level (PSMSL) for the period 1937-2003.

The different water levels (hourly, yearly, high and low waters) were reduced to the same reference level, and their quality was checked. Finally, all available data were combined to construct a time series for the yearly mean sea level for the period 1927-2006. Unfortunately, some gaps are still present in the time series: years 1930, 1940-1942, 1944 and 1950 are missing.

Up to four models have been fitted to the data (Figure 2). With the conventional linear regression, we get a sea level rise (SLR) equal to 1.69 mm yr^{-1}. This SLR is greater than those reported in previous studies (Van Cauwenberghe, 1995; 1999). This SLR is quite surprisingly very close to the value (1.70 mm yr^{-1}) reported by the IPCC for the global average sea level rise (Bindoff et al., 2007). A piecewise linear model suggests a change of SLR in 1992. Prior to 1992, the slope is equal to 1.41 mm yr^{-1} and after it is equal to 4.41 mm yr^{-1}. The latter is remarkably close to the global average rate of 4.0 mm yr^{-1} obtained by Holgate and Woodworth (2004) for the period January 1993 to December 2002 from tide gauges data. A decade-long satellite altimetry data set shows that sea level has been rising at a rate close to 3 mm yr^{-1} since 1993 (Bindoff et al., 2007). With a second order polynomial model, we get a slope varying between 0.72 mm yr^{-1} in 1927 and 2.63 mm yr^{-1} in 2006. The acceleration of the SLR is equal to 0.012 mm yr^{-2} which is almost equal to that (0.013 $\pm$ 0.006 mm yr^{-2}) estimated by Church and White (2006) for the global mean sea level. The last model, a 3rd order polynomial model, indicates the SLR might have been sometimes in the past as large as it is today.

Further details on this trend analysis are given in Ozer et al. (2008).

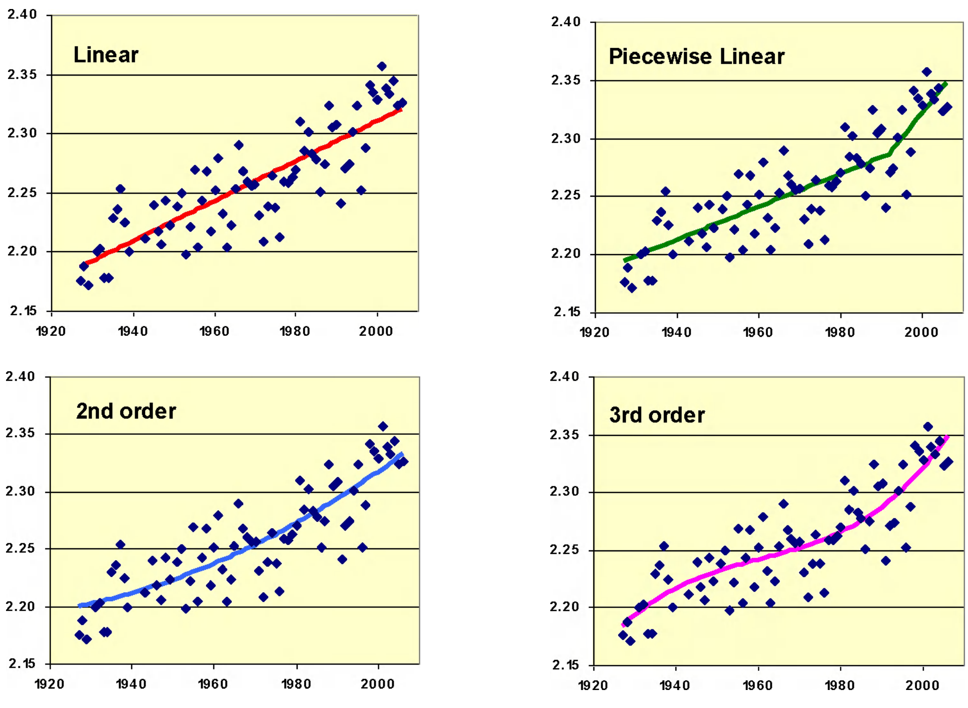


Figure 2: Trend analysis of relative mean sea level at Oostende over the period 1927-2006. (Top left: linear regression; top right: piecewise linear; bottom left and right: 2nd order and 3rd order polynomial models)

2.2.2.3.2 Data analysis of waves and wind measurements

Measurements of waves and wind were obtained from MDK and were downloaded from the website of Hydro Meteo Centrum Zeeland. The longest time series extends from 1978 till 2007. Furthermore the meteorological forecasts of the Det Norske Meteorologiske Institutt (DNMI) were received for the period 1955-2006. From these meteorological fields, the time series at Westhinder was extracted for analysis.

To obtain uniform time series, the monthly mean of the parameters were calculated. These monthly mean time series then were split in a long term trend, a seasonal cycle and the residue, following the methods, proposed in the NOWESP project (Visser et al., 1996). The long term trend was calculated on the basis of a moving average filter, with a period of 48 months. Gaps in the monthly mean time series were interpolated, taking into account the long term trend and the seasonal cycle. Apart from the extraction of the long term trend, also a simple linear regression was calculated to assess the overall trend in the monthly mean time series.

In Figure 3a, the long term trend is presented for the significant wave height at four stations in Belgian and Dutch coastal waters. A clear variability is apparent with a period of about 7 years, with higher waves around 1987, 1994 and 2001. The period is related to the variation in the North Atlantic Oscillation (NAO), which shows variations with periods of 17 years, 7.7 years and 2.4 years (Loewe and Koslowski, 1994). A clear long term trend is not visible in the significant wave heights. The linear regression shows a small decrease of -0.0013 m yr^{-1} and -0.0027 m yr^{-1} at Bol van Heist and Brouwershavensche Gat 2 respectively, and a small increase of 0.0024 m yr^{-1} at Scheur West.

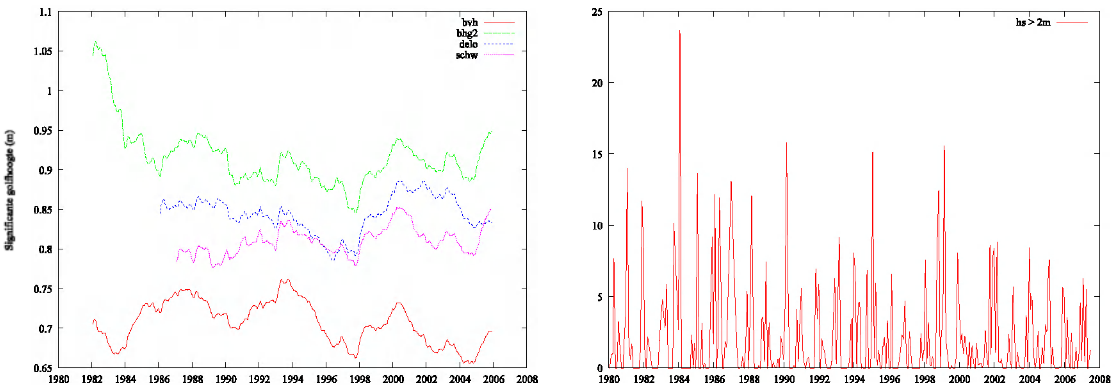


Figure 3: (a) Left: Long term trend of the monthly mean significant wave height at four measuring stations Bol van Heist (bvh), Brouwershavensche Gat 2 (bhg2), Deurloo (delo) and Scheur West (schw) for the period 1980-2007. (b) Right: Percentage significant wave

For most stations a small decrease is found in the percentage of waves higher than 2 m or higher than 3 m (Figure 3b). At the station Brouwershavensche Gat 2, the percentage waves higher than 2 m decreases from 8.4 % in 1980 to 4.6 % in 2007.

The maximum wave height during a month increases marginally for the stations Bol van Heist and Scheur West, but decreases for Brouwershavensche Gat 2 and Deurloo. Overall, no clear trend can be found in the significant wave height at the BPNS. The small tendency for lower waves needs to be confirmed.

In the long term trend of the wind speed at Westhinder, extracted from the meteorological prediction of DNMI (Figure 4a) an increase in monthly mean wind speed could be observed between 1955 and 1968, after which a small decrease of monthly mean wind speed occurs. This decrease in wind speed is still more apparent since the period 1990-1995. The decrease in wind speed agrees with the small decrease in significant wave height at the BPNS. Remark that analysis of the (too) short time series at the measuring stations, especially at Westhinder, could give misleading conclusions.

For the maximum wind speeds and the percentage of wind speeds higher than a certain threshold, the results are less clear. The linear regression doesn't show consistent results for the different stations and for the different thresholds used. As an example the percentage of wind speeds higher than 8 Bft. are shown in Figure 4b for the wind speed at Westhinder, extracted from the meteorological prediction of DNMI. Here an increase in percentage seems visible for the period 1955 till 1990. After 1990 a decrease in percentage is found. These results however don't show up in a simple linear regression. More refinement in the models used could improve the results.

For comparison, some results, found in literature, are summarised here. Remark that a good overview of studies on the changing storminess can be found in Smits et al. (2005). In Siegismund and Schrum (2001) data from the NCEP/NCAR reanalysis were used to analyse the wind speed and the wind direction over the period 1958-1997 over the entire North Sea. An increase of about 10 % was found in wind speed over that period. Also the measurements of the cubed wind speed in Utsira (Norway) shows an increasing trend over the period 1950-2000 (OSPAR Commission, 2000). These NCEP/NCAR data were also used by Weisse et al. (2005) to force a regional climate model for the North Atlantic Ocean. The results were analysed to look for trends in the occurrence of moderate and severe storms. They found important regional differences with opposing trends above and below 45°N. In the Southern North Sea, an increasing trend in the storminess was found for the period 1958 till 1990-1995. Since 1990-1995 a decrease in storminess occurs at the Southern North Sea. On the other hand, a recent study of Smits et al. (2005) analysed a set of high quality wind speed measurement in The Netherlands. They found a continuous decrease of the number of storms over The Netherlands from 1962 to 2002. They concluded that the inhomogeneities in the NCEP/NCAR analysis data were the main cause of the discrepancy between their results and the results of Siegismund and Schrum (2001) or Weisse et al. (2005). It is clear that further research is needed to come to a conclusive answer.

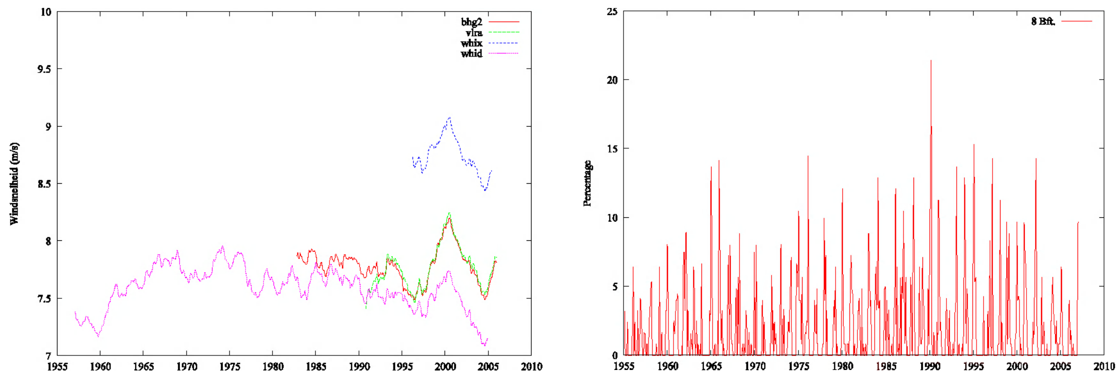


Figure 4: (a) Left: Long term trend of the measured wind speed at Brouwershavensche Gat 2 (bhg2), at Vlakte van de Raan (vlra) and at Westhinder (whix) and long term trend of the wind speed at Westhinder, extracted from the meteorological prediction of the DNMI

Concerning the wind direction, an increase in south-western winds is found over the last decades. This is visible in the larger increase in the winds towards the north, when analysing the long term trend of the wind components separately (Figure 5a). When looking the variation in the wind density function (Figure 5), as defined in Siegismund and Schrum (2001), over the decades, an increase, in frequency or in intensity, of west-south-western winds is visible. This agrees with the results, obtained in Siegismund and Schrum (2001).

Further details on this trend analysis of waves, wind speed and wind direction can be found in Van den Eynde et al. (2008).

2.2.2.3.3 Analysis of sea surface temperature

For the determination of the primary effects of climate change, the evolution of sea water temperature is also of importance. As shown in Ponsar et al. (2008), the sea water temperature is of great importance for the changes in the marine ecology. Also for the fisheries sector, the variations of sea water temperature can have large effects, e.g., on the spatial distribution of the marine species. Since for the fisheries, not only the Belgian coastal waters are of importance, this analysis is performed for the entire North Sea.

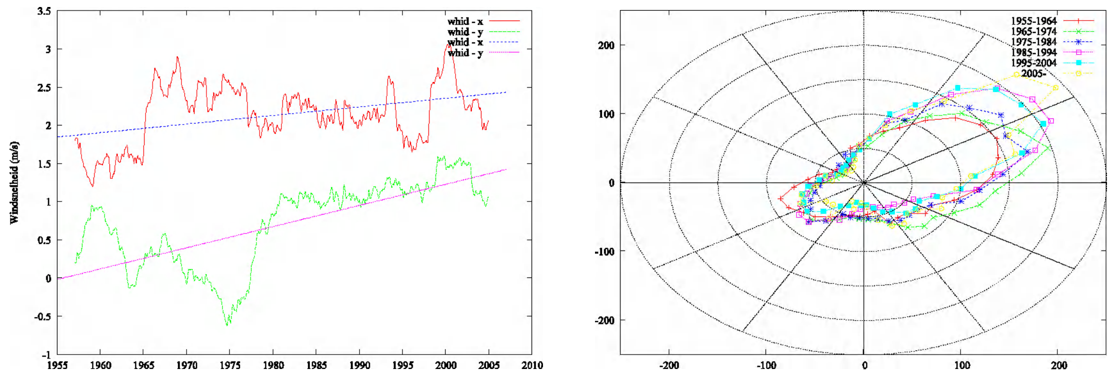


Figure 5: (a) Left: Long term trend of the wind speed components (x: wind to the east, y: wind to the north) and (b) Right: wind density function for different decades, from the wind at Westhinder, extracted from the meteorological prediction of the DNMI

The data, which were used for the analysis, were data from the World Ocean Database 2005 (WODB), which were received via the Belgian Marine Data Centre (BMDC). More than 127000 sea surface temperatures were obtained in an area from 4°W to 12.5°E and from 51°N to 61.5°N and over a period from 1971 to 2007. Since no data in the Channel and the Irish Sea were obtained, also some data from the British Oceanographic Data Centre (BODC) were requested. Almost 19000 measurements were obtained in a larger area.

The data were combined to make monthly mean time series for 36 boxes in the entire North Sea. The entire area considered extends from 12°W to 12°E and from 49°N to 61°N. Boxes were made with a resolution of 2° in latitude and 4° in longitude. One must remark that in only 15 boxes, sufficient data were available to make monthly mean time series, for which in at least 50 % of the months, measured data were available. Using the BODC data, time series for 5 more boxes were prepared, for which in at least 25 % of the months, some measurements were available. As discussed above, the missing data were interpolated using the long term trend and the seasonal cycle (Visser et al., 1996). It is clear however, that the data from the BODC are subject to large uncertainties.

In the long term trend in the different boxes a clear increasing trend can be observed (Figure 6a for the data from WODB). Furthermore, also here a natural decadal variability is apparent, with a period of about 7 to 8 years. This agrees with the variability in the NAO, as reported in Sündermann et al. (1996). The slopes of the linear regression for the same boxes are presented in Figure 6b. The values vary between 0.023 °C yr^{-1} in the Skaggerak and in the North of the North Sea to 0.053 °C yr^{-1} in the central North Sea and the southern North Sea. These values roughly agree with the values found in literature (e.g., Ponsar et al., 2007). Further details on this trend analysis of sea water temperature can be found in Van den Eynde et al. (2008).

2.2.3 Climate change scenarios

As mentioned, a way of dealing with the uncertainties of possible impacts is to draw a series of climate change scenarios. In the framework of the CLIMAR project, three scenarios were presented. These scenarios are based on similar scenarios which were set up in the neighbouring countries, like The Netherlands, the United Kingdom and Germany.

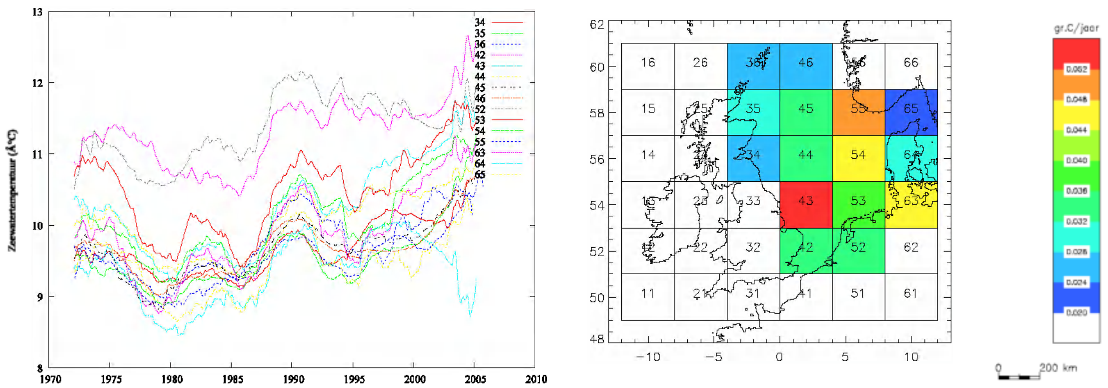


Figure 6: (a) Left: Long term trend for the sea surface temperature in different boxes in the North Sea (b) Right: Trend, calculated by a linear regression of the sea surface temperature in different boxes in the North Sea.

Five scenarios were drawn for 2040 (mid-term) and 2100 (long-term): two moderate (M, M+) scenarios, two warm scenarios (W, W+) and a worst case scenario (WCS). In the M and W scenarios, there is no significant change in air circulation patterns, and the precipitation increases both in summer and in winter with about 3 % per °C of air temperature increase. In the M+ and W+ scenarios, there are significant changes in air circulation patterns and the precipitation increases more in winter (about 7% per °C of air temperature increase) and decreases in summer (about 10% per °C of air temperature). This decrease in summer precipitation is mainly attributed to the decrease in the number of rainy days. A strong change in air circulation induces warmer and moister winter seasons and increases the likelihood of dry and warm summer time situations.

In Table I the five scenarios are presented for 2040 and in Table II for 2100. The scenario for 2100 is simply a linear interpolation of the values for 2040. Note that the sea level rise in the last improbable 'worst case' scenario, accounts for some unexpected but possible effects, such as the massive melting of ice sheets and the stopping of the Thermohaline Ocean Circulation. This last scenario was proposed by Brooks et al. (2006).

Table I: Climate change scenarios 2040

	M	M+	W	W+	WCS
Air temperature	+ 1° C	+ 1° C	+ 2° C	+ 2° C	+ 2° C
Change air circulation	No	Yes	No	Yes	Yes
Winter precipitation	+ 4 %	+ 7 %	+ 8 %	+ 14 %	+ 14 %
Wind velocity	0 %	+ 2%	- 1 %	+ 4 %	+ 4 %
Summer precipitation	+ 3 %	- 10 %	+ 6 %	- 20 %	- 20 %
Sea water temperature	+ 1.2 °C	+ 1.2 °C	+ 1.7 °C	+ 1.7 °C	+ 1.7 °C
Mean sea level	+ 30 cm	+ 30 cm	+ 40 cm	+ 40 cm	+ 100 cm
Storm surge level	+30 cm	+40 cm	+45 cm	+60 cm	+70 cm

Table II: Climate change scenarios 2100

	M	M+	W	W+	WCS
Air temperature	+ 2° C	+ 2° C	+ 4° C	+ 4° C	+ 4° C
Change air circulation	No	Yes	No	Yes	Yes
Winter precipitation	+ 8 %	+ 14 %	+ 16 %	+ 28 %	+ 28 %
Wind velocity	0 %	+ 4 %	- 2 %	+ 8 %	+ 8 %
Summer precipitation	+ 6 %	- 20 %	+ 12 %	- 40 %	- 40 %
Sea water temperature	+ 2.5 °C	+ 2.5 °C	+ 3.5 °C	+ 3.5 °C	+ 3.5 °C
Mean sea level	+ 60 cm	+ 60 cm	+ 93 cm	+ 93 cm	+ 200 cm
Storm surge level	+60 cm	+80 cm	+80 cm	+130 cm	+240 cm

2.2.4 Numerical models

A last method to evaluate the primary impact of global climate changes is the use of numerical models. Three types of numerical models are available: hydrodynamic models, wave models and sediment transport models. These models will be used to simulate the current situation and to calculate, e.g., the maximal bottom stress or amount of mud deposited at the bottom. The variations in these parameters, under the influence of the climate changes as described in the scenarios can be assessed.

2.2.4.1 Hydrodynamic model

For the analysis of the currents, the bottom stresses and the tidal amplitude, the OPTOS-BCZ model is used, which is an implementation of the three-dimensional hydrodynamic COHERENS software (Luyten et al., 1999) on the BPNS. The model has a resolution of about 820 m to 772 m and has 20 σ-layers over the water column. The model is coupled with two other regional hydrodynamic models, which provide the boundary conditions. Two periods were selected for the analysis. The period March 1st 2000 till April 1st 2000 is a 'normal' period, with a mean wind speed close to the long-time average. The period January 22th 1994 to January 31th 1994 is a period with high winds. For the current situation and for the five defined climate change scenarios, the mean and maximum currents, the mean and maximum bottom stresses and the tidal range, are calculated.

As an example, in Figure 7, the magnitude of the mean tidal currents in the Belgian coastal waters are presented for the current situation (left), together with the changes to the magnitude of the mean tidal currents in the Belgian coastal waters for the Worst Case Scenario (scenario 5), defined above (right), *i.e.*, for a sea level rise of 2 m and a wind speed increase with 8 %. Detailed analysis shows that in 75 % of the model grid points, the mean current is lower in the WCS, with a maximum decrease of 46 % and a maximum increase of 25 %. Histograms (see Figure 8), can give more information on the change of the mean currents or on the tidal amplitude on the BPNS. The histogram of the tidal amplitude clearly shows the increase in tidal amplitude on the BPNS.

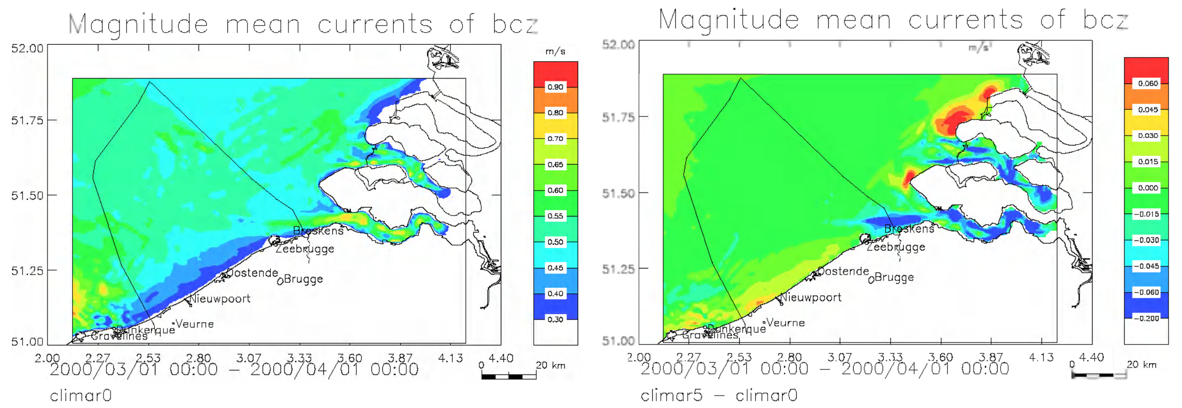


Figure 7: (a) Left: Mean currents on the BPNS as simulated with the OPTOS-BCZ model for the present situation (b) Right: Changes to the mean currents for the Worst Case scenario.

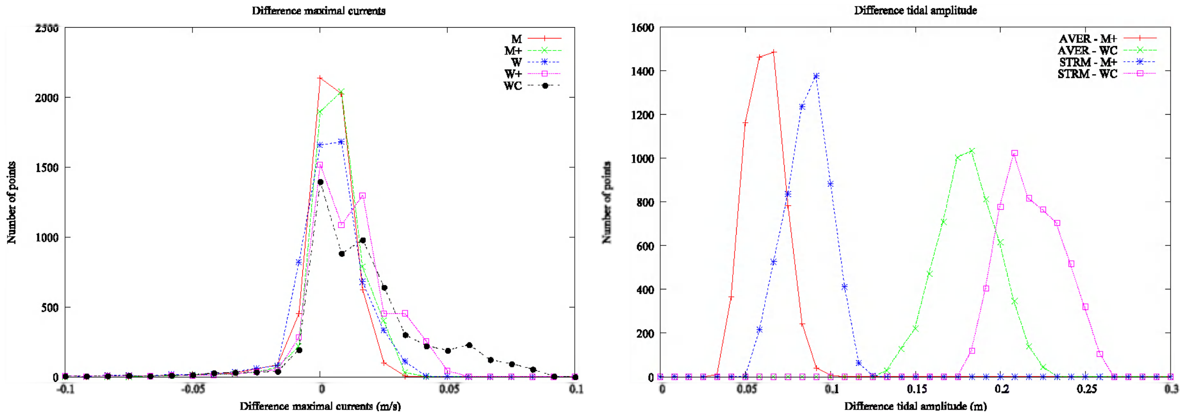


Figure 8: (a) Left: Distribution the change in the mean currents on the BPNS as simulated with the OPTOS-BCZ model for the present situation and for the different climate change scenarios (b) Right: Distribution of the change in the tidal amplitude on the BPNS as simulated with the OPTOS-BCZ model for the present situation and for the different climate change scenarios.

More information of these results can be found in Van den Eynde (2011).

2.2.4.2 Wave model

For the analysis of the waves, two different models are being used, the mu-WAVE model (Van den Eynde, 1992), based on the HYPAS model and the SWAN model (Holthuijsen et al., 1989). The SWAN wave model has been implemented for the BPNS, in the framework of the project. The same two periods are used for the analysis as for the hydrodynamic model.

The mu-WAVE model has been used to evaluate the influence of the climate change scenarios on the significant wave height in the Southern North Sea. The influence of the sea level rise is very limited in the deeper waters of the Southern North Sea. The increase in wind speed, obviously, has some influence on the increase of significant wave height. For the WCS, the increase of 8 % in wind speed, induces an increase in maximum significant wave height of about 50 cm.

The SWAN model is used to calculate the propagation of the waves from offshore to the Belgian coast area. A model with a much higher resolution is used here, but the SWAN model gives only stationary results. An example of the SWAN model is given Figure 9. In the left plot, the propagation of wave with a significant wave height of 3.5 m is given to the Belgian coast. Due to the wind and to a less extent, due the shoaling, the wave height increase on the sand banks offshore, then the wave breaking increases and near the coast, the significant wave height is less than 2.0 m in the western part of the Belgian coast. In the left plot, the change in wave height is given, due to a sea level rise of 93 cm (scenario W). More offshore, the waters are deeper, with slightly lower significant wave heights. More to the coast however, due to the larger water depths, less wave breaking occurs with increasing wave height near to coast. Near to western coast, the increase in significant wave height can be 30 to 40 cm. Due to a SLR of 93 cm, a mean increase in wave height over the entire coast can be expected of 10 to 25 cm.

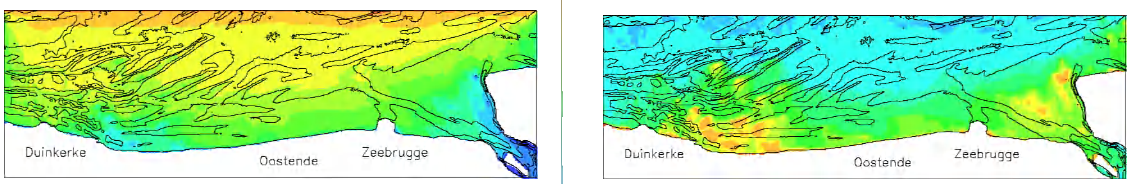


Figure 9: (a) Left: Propagation of a wave with significant wave height of 3,5 m, under the influence of a wind speed of 16 m/s and perpendicular to the to the Belgian coast.
(b) Right: Changes in significant wave height due to a sea level rise of 93 cm.

More information can be found in Van den Eynde (2011).

2.2.4.3 Sediment transport model

The sediment transport model mu-STM was used to evaluate the effect of the climate change scenarios on the siltation of the fair channels towards the Westerschelde and the sea harbour of Zeebrugge. The currents are calculated by the MU-BCZ model, a two-dimensional hydrodynamic model, while the waves are calculated by the mu-WAVE model, mentioned above. The mu-STM model was already used to model the high turbidity area in the Belgian coastal zone (Fettweis and Van den Eynde, 2003).

Three different simulations were executed: one with a continuously hourly dumping at dumping site Zeebrugge-Oost (sim1), one with one big dumping at Zeebrugge-Oost (sim 2) and a last with no dumping but with boundary conditions, that were developed from satellite images, allowing material to enter the model grid (sim3). The effect of the five defined CLIMAR scenarios were investigated on the amount of material which is deposited in two zones: zone 1 near the fair channels, and zone 2 near Zeebrugge.

In Figure 10 the amount of material deposited in the zone 1 at the last day of the three simulations is presented, for the actual situation and for the different climate change scenarios. Unfortunately, no clear conclusions can be formulated. Only in simulation 3, an increase in deposition in the fair channels is found, while the results for the two other simulations show much more variability.

Therefore no conclusive answer can be formulated on the evolution of the siltation of the fair channels in the future. More research is clearly needed.

More information on the simulations and the results can be found in Van den Eynde (2011).

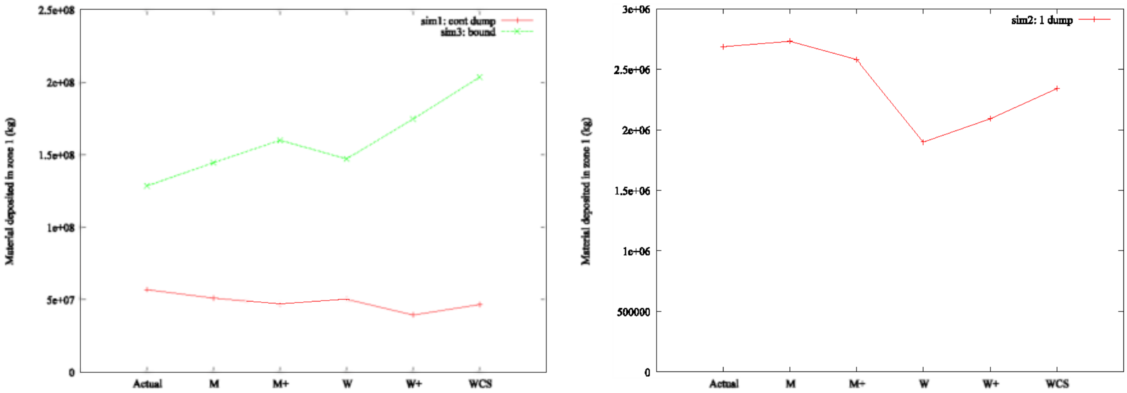


Figure 10: Amount of material deposited on the bottom at the end of the simulation in zone 1 around the fair channels for the different climate change scenarios (a) Left: simulations 1: hourly dumpings & simulation 3: boundary conditions (b) Right: simulation 2: one dumping.

2.3 SECONDARY IMPACTS

2.3.1 Deduction of secondary impacts both on the marine ecosystem as well as on other socio-economic activities – Identification

2.3.1.1 Regional

A literature study has been conducted to identify all secondary impacts taking place on a regional scale (Belgian Part of the North Sea), classified according to their ecological, social and economical nature.

At first a general terminology has been worked out, resulting in different effect categories. These effect categories group a range of effects (Table III). An "effect" gives a more detailed description of the climate change impact defined under the "effect category". While the "effect categories" are common for all sectors, the "effects" can be sector-specific. In this way impacts can be compared over sectors and allows for extrapolation towards the regional level (bottom-up).

The final list of effect categories considered in the CLIMAR project is given in Table III. A detailed description can be found in Volckaert and De Sutter (2011).

Table III: Considered effect categories of CLIMAR

Effect categories	*Effect (definition + example)*
Ecological effect categories (mainly direct effects)	
Water quality	Related to physico-chemical aspects such as oil pollution, turbidity, salinity
Habitat quality	Leading to degradation (or improvement) of coastal/marine habitat (*e.g.*, litter on beach)
Habitat change	Change/loss of natural habitat such as loss of fishery grounds, nature areas or change due to offshore structures
Ecosystem productivity	Change in the timing, abundance or composition of primary producers
Geographical shift	Moving/replacement of species (composition) due to climate change (temperature increase, etc.)
Establishment of non-indigenous species	Introduction and survival of species not naturally occurring in Western Europe
Ecosystem component interactions	Decoupling of phenological relationships with impact on recruitment, food availability, etc.
Biodiversity	Change in biodiversity as a result of one or more of the described effect categories
Other biological events	Other biological effects such as harmful blooms
Economical effect categories (mainly indirect effects)	
Change in production	Decrease in production due to destruction of certain facilities, damage to boats, difficulties/restrictions for executing job (# sea days), ecological consequences, etc. Increase in production due to better ecological consequences, etc.
Production value	Expressed in terms of the "price of the product" and determined by the availability of the product and the changes in cost (~ exploitation, damage)
Exploitation costs	The costs needed to exploit a unit (quantity) of the considered product (~activity, transport)
Damage costs	Damage as a function of maintenance and insurance costs *e.g.*, damage to private or public properties (buildings, equipment, stocks, machinery), damage to transport infrastructure, damage to service networks (gas, water, electricity, telecommunication, coastal infrastructure)
New opportunities	Such as new activities or new "climate proof" technological initiatives
Economic result	Expressed as profit (positive) or loss (negative) and calculated by decreasing the total turnover (= revenues) with the total costs (wages, rent, fuel, raw materials, interest on loans and depreciation)

Social effect categories (mainly indirect effects)	
Attractiveness coastal and marine area	Overall term used to describe the degree in which the society attaches importance to the coast (recreational value, leisure opportunities)
Employment	Direct loss/ increase of jobs
Human settlement	Availability and occupation of coastal housing units
Safety	Risk of accidents, *e.g.*, flooding of houses (human settlement), flooding of business property, accidents at sea (transport), accidents during work activity (exploitation)
Accessibility	Accessibility of the coast expressed in time needed to reach the coast and the status of the transport infrastructure (public and road) Accessibility of the marine ports expressed in time needed to enter the port
Health	Health effects considered are mortality in function of extreme temperatures (heat, cold); stress related problems; diseases due to bad water and seafood quality
Cultural value	Coastal cultural heritage and values
Welfare (individual and family life)	Indirect effects as a result of social changes (changes in employment, human settlement, safety, health, etc.). It deals with the aspect of "life quality" (~purchasing power; ~family relationships).

2.3.1.2 Sectoral

2.3.1.2.1 General

Climate change will affect sectors in a different way, but also within a sector differences can be observed depending on the activity considered. The sectors selected for the CLIMAR study are coastal flooding, fisheries and tourism. The different sectors have been divided into several subsectors (only when relevant). For example for the sector tourism following subsectors have been identified: beach tourism, water tourism, ecotourism, gastronomic tourism, cultural tourism, health tourism, holiday and business.

As a base for the identification of the secondary impacts, the results were taken from the primary impact assessment. At first, a process diagram has been worked out per marine sector linking these primary effects with identified secondary impacts (subdivided into ecological, social and economical effects).

Secondary impacts have further been worked out in more detail per subsector. The relevant secondary effects (positive and negative) have been described per effect category, with a distinction in direct (direct result of primary effect) and indirect (result from another secondary effect) effects. An indication of the importance (priority) of the climate impact to the sector has been given taking into account their already existence or their increased risk of occurrence, the time needed to plan and implement adaptation responses, their range of action with respect to sensitive areas.

Finally, in developing adaptation strategies, it will be necessary to assess the relative sensitivity of the sector to other non-climate risks. It could be that other external factors (e.g., demographic change, international market) are much more determining the future evolutions of the sector, than that climate change does. So alongside climate change scenarios, socio-economic scenarios have been developed to take these external non-climate changes into account.

All information has been summarised per sector in an impact table, with a distinction between ecological, economical and social impacts.

2.3.1.2.2 Case study of coastal flooding

Secondary climate change impacts resulting from sea level rise and increased storminess on coastal flooding are identified and described in 3 different effect categories: ecological, economic and social effects. This step is based on literature and expert knowledge.

The identified ecological impacts of climate change related to coastal flooding are changes in water quality, and associated ecological effects, due to altering circulation patterns around defence structures or due to changing currents around sand extraction sites. Ecological effects are habitat change and changes in biodiversity, because the equilibrium of natural ecosystems is disturbed due to the construction of defence structures. Turbidity of the water around extraction areas will also affect water quality. North Sea sand extraction also threatens marine habitats. Most important ecological effect is loss of beach area, but beach nourishments can compensate for this loss. The construction of defence structures can also affect beach erosion or accretion. On the other hand, defence structures are good environments for colonisation by marine fauna and flora. Finally, flooding events can lead to loss of specific habitats whereas under managed retreat habitat diversity can increase.

Secondary economical effects of climate change can be change in production when offshore economic infrastructure gets damaged during extreme storms and change in production value due to increased costs for protection against sea level rise. Most important economical effect is higher direct damage and associated insurance costs due to flooding (damages to buildings, industry, agriculture, transport infrastructure, service networks, coastal defence structures, vehicles, ...). Damages to industrial and agricultural properties will subsequently lead to temporary or permanent decrease in production. Indirectly, this can result in economic losses at supplier and customer companies. Climate change can also lead to new opportunities: economic activities such as aquaculture or land reclamation can be coupled to alternative offshore defence measures.

Secondary impacts of climate change on the social system are related primarily to safety for people (occurrence of flooding casualties and higher flooding risks).

Other social effects are accessibility (difficult navigation to and through ports due to the construction of defence structures and obstruction due to damages to transport infrastructure), employment (temporary or permanent loss of jobs in flooded areas and increase in jobs for the construction of new defence structures), attractiveness (loss of space for leisure activities due to beach erosion or increase in beach area due to nourishments, disturbed beach view due to defence structures on the coastline or offshore and more natural and/or recreational area in account of managed retreat) and welfare (flooding damages and casualties and temporary or permanent loss of jobs in flooded areas).

2.3.1.2.3 Case study fisheries

More than 50 secondary effects were identified. The secondary effects identified under the ecological effect categories are strongly linked and reflect the complexity of the ecosystem. The literature study, dealing with the impacts of climate change on the ecological parameters already indicates that all trophic levels of the food web are affected by climate change. The status of a fish stock, which forms a component of the ecosystem considered, is therefore associated with the whole ecosystem and the changes it is undergoing due to climate change. Many studies consider temperature as the most important factor in relation to fish stocks and analyses are performed using temperature as main indicator (Beaugrand, 2004; Brander, 2006; 2007; Cook and Heath, 2005; deYoung et al., 2008; Frid et al., 2008; ICES, 2007; 2008a; 2008b; Klyashtorin, 2001; Perry et al., 2005; Rijnsdorp et al., 2010; Stiansen et al., 2005). Thus, the status of the (potential) commercial fish stocks and the effect of (future) water temperature rise were considered for quantification. The effect that several other primary impacts like acidification, turbidity, etc. can have on fish stocks was described but not further quantified.

In order to identify the secondary effects classified under the economical effect categories the fish stocks, e.g., potential catch, are considered as production. Hence economical effects are closely linked with the status of the different fish stocks. Primary effects like storminess and changes in prevailing winds can influence the operational functioning of the fleet and reduce the income of the ship owners.

Secondary effects identified under social effect categories comprise mainly safety for crew and vessel, welfare and employment.

More information can be found in Vanderperren et al. (2011a).

2.3.1.2.4 Case study coastal tourism

For the case study of tourism the most important primary effects are temperature and air circulation patterns (precipitation, wind and currents) both determining the climatic conditions at the coast and sea level rise increasing the risks of natural hazards such as flooding and coastal erosion.

Other important secondary impacts besides the attractiveness of the coast in terms of pleasant climatic conditions and the loss of dune/beach area due to flooding or erosion, are the occurrence of sea mammals (geographical shift) as the food availability and temperature changes, increased damage costs to marinas due to sea level rise, changed accessibility of the coast due to damage infrastructure and an overall change in the turnover of the tourism sector including the creation of new commercial activities (in water tourism, ecotourism). As can be seen climate change can influence the sector both in a negative and positive way.

A complete list of the identified secondary effects can be found in Volckaert and De Sutter (2009).

2.3.2 Deduction of secondary impacts both on the marine ecosystem as well as on other socio-economic activities – Quantification

2.3.2.1 Quantitative description of the marine sectors

A quantitative description, spatial, intensity, social importance (valuation), economical importance (jobs, profit, etc.), has been executed for fisheries, coastal flooding and tourism based on available literature, data bases and personal communications with the sector. The results have been described in a separate subdocument per sector. A brief summary is given in the next paragraphs.

2.3.2.1.1 Case study coastal flooding

The Belgian coastal plain is a very intensively used zone. Directly on the shoreline more than 50 % of the area is occupied by industry or housing, while the low-lying polders further inland are mainly used for agricultural purposes. In Van der Biest et al. (2009a) a quantitative description is given of all the types of land use and infrastructure threatened by coastal flooding: sea defence structures, nature, buildings, industry and business, agriculture and service and transport networks.

The quantification of the main economical and social secondary effects is based on a numerical model developed by Flanders Hydraulics Research and University of Ghent: the LATIS software version 1.2 for damage and victim calculations. To each land cover type and object in the Belgian coastal plain a maximal damage value in € is attributed. The victim calculation is based on the population number per municipality (National Instituut voor Statistiek, 2007; Wikipedia, 2008).

2.3.2.1.2 Case study fisheries

The Belgian fisheries sector is currently going through a crisis and many ship owners are on the verge of bankruptcy. Therefore, it was necessary to focus on the present situation of the Belgian fisheries sector and its most important drivers, in order to get a better understanding of the impacts induced by climate change and as input for the development of adaptation strategies,.

A document giving a detailed description of the fisheries sector/fleet was drafted and addressed the current situation and the external factors which (may) affect the future of the fisheries sector and make it more vulnerable to climate change impacts (Vanderperren and Polet, 2009a). Reference year for the case study fisheries is 2007. Some relevant findings:

Fleet composition

The number of fishing vessels dropped from 457 vessels in 1950 to only 102 vessels end 2007, making the Belgian fleet the smallest in Europe. The fleet halved between 1960 and 1980, decreased further to become rather stable between 2000 and 2005. Since 2006 the number of vessels is decreasing again. Total tonnage and total engine power of the fleet did not decrease accordingly over the last decades, indicating that the vessels became larger, with a higher individual capacity. In 1991 the average tonnage and engine power amounted to almost 25000 GT and 80000 kW. Since 1992 these averages decreased systematically to the current level. The Belgian Fisheries administration divides the fleet into sub fleets based on the engine power of the vessels (Tessens and Velghe, 2007).

Fishing method

The Belgian fishing fleet consists mainly of beam trawlers, targeting sole and plaice. Beam trawls are also used to fish for shrimps and Norway lobster. Beam trawling is a highly mixed fishery and by consequence vulnerable to management measures protecting single fish stocks like cod or plaice. Beam trawling as a fishing method couples a number of problems such as high fuel and material consumption, heavy seafloor impact and low species and size selectivity. Otter trawls and passive fishing methods are used to a lesser extent.

Fishing grounds /quota/ landings

The Common Fisheries Policy (CFP) determines the Total Allowable Catches (TACs) for most significant commercial fish stocks. These TACs are catch limits which are set per fish species and ICES fishing area, and distributed over the countries based on historical rights and the principle of relative stability. The Belgian fleet is active in several ICES-areas, the most important are: Central North Sea (IVb), Southern North Sea (IVc), Irish Sea (VIIa), Eastern Channel (VIId), Bristol Channel (VIIf) and South East of Ireland (VIIh,j,k) (Tessens and Velghe, 2008). Almost all commercial species caught by the Belgian fleet fall under a quota regulation. The annual landings of Belgian vessels decreased from roughly 35000 ton in the late eighties-early nineties of the twentieth century, to less than 22000 ton nowadays. Compared with 2006 the landings for 2007 increased slightly. As most Belgian vessels fish with beam trawls, their landings consist mainly of demersal species. The top 10 of landed species in 2007 indicates that plaice (5501 ton) and sole (3676 ton) are the most important species, followed by ray (1811 ton), squid (1607 ton) and cod (1074 ton) (Tessens and Velghe, 2008).

Economic / social

The gross added value of fisheries on production level is very low compared with the gross domestic product, namely 0.04 %; compared with the total value of agro- and horticulture it's 1.9 %. However, Belgium has a very small coast line and the sea fisheries sector is very important on a regional level (Tessens and Velghe, 2007; Demeyere, 2003). Fisheries has its impact on the socio-economic structure, like specific trades correlated with fisheries, distribution chain, fish processing companies, fish traders, catering industry and coastal tourism.

External factors

(Potential) external factors influencing the fishing industry now and/or in the future are identified: fuel prices, fish prices and national and international regulations/policy (Common Fisheries Policy, precautionary approach – Maximum Sustainable Yield, Total Allowable Catch, Limitation of fishing effort, technical measures, recovery plans, ecosystem approach, ban on discards, European Fisheries Fund and National Strategic Plan).

2.3.2.1.3 Case study coastal tourism

The Belgian coast is a traditional holiday destination offering large beaches for sun bathing and recreational activities, valuable nature areas to explore and a range of shopping and gastronomic possibilities. This all concentrated on a small distance of 65 km, easily accessible by road or public transport. As a result our coast has an important economical and social value.

With its close connections to the environment and climate itself, tourism is considered to be a highly climate-sensitive economic sector. Despite the significant growth in research on tourism and climate change there are considerable gaps in the previously published research regarding the knowledge of climate change adaptation and mitigation. With the selection of the sector tourism as third case study, a first attempt will be taken to tackle these problems for the Belgian coast tourism sector.

Based on the natural and socio-economical values of the coast three main types of coastal tourism further divided in a number of subsectors, have been distinguished for the purpose of the CLIMAR project: recreational tourism (beach, water and ecotourism), economical tourism (holiday, shopping, gastronomy, attractions and museums) and niche tourism (historic/cultural, health). A document giving a detailed description per subsector was drafted based on available studies and addressed the current situation, the socio-economic importance and the external factors which (may) affect the sector and make it more vulnerable to climate change impacts (Volckaert and De Sutter, 2009). Some relevant findings:

- The favourite tourism activities at the coast based on a questionnaire for recreational tourists in commercial accommodations (> 18 years) are (in descending order) walking, visit to restaurant or pub, shopping, sun-bathing and swimming. This activity pattern is roughly the same for the day tourist and the second stay tourism (Westtoer et al., 2009a).

- The most important reasons for a successful stay at the coast have been the weather (37%), the satisfaction of the accommodation (16%) and the perception value of the coastal landscape (9%) (Toerisme Vlaanderen, 2007).
- In total 18.2 million day tourists were counted in 2007, with an increase for April (Easter period; 8% of total number of tourists) and a peak in July and August (high seasons: 35.1 % or in total 6.38 million tourists in 2007) (Westtoer et al., 2009b). Recently published figures show again a decrease for 2008 with 16.4 million day tourists due to the bad summer (Westtoer, 2008).
- Our coast has an important economical and social value. In 2008 coastal tourism in Belgium has generated a global turnover of approximately 2.6 billion Euro and approximately 13,000 direct jobs (Westtoer, 2008).

Despite the climate-sensitivity of the coastal tourism sector, it should be mentioned that in the day-to-day practice of tourism industry, climate factors are overwhelmed by all kinds of other influences: country stability, financial climate, transport conditions (fuel price), fashion trends, availability of leisure time, terrorism, international competition, etc.

2.3.2.2 Socio-economic scenarios

As mentioned under Section 2.1 (Methodology), socio-economic scenarios (both mid and long-term) should be considered in order to quantify the overall impact. Socio-economic (external) factors can both influence the “elements at risk” (*e.g.*, population growth will lead to more people at risk) and the vulnerability to a certain climate risk (*e.g.*, increased fuel price will worsen economical impact on fisheries).

An analysis has been performed for each sector to identify the determining socio-economic parameters. The majority of these parameters (*e.g.*, population growth, economical growth) can be used for the three sectors considered (coastal flooding, fisheries and tourism), while others are very sector specific (*e.g.*, fuel price). Some parameters have been defined on a national scale, while others have been based on more appropriate data for coastal municipalities (Arrondissement Oostende).

The development of socio-economic scenarios (in time) is a complex and time-consuming task. However, existing scenarios can be borrowed or adapted from the literature. The Federal Planning bureau has made, for the "Milieuverkenning 2030" (Van Steertegem, 2009), scenarios related to a number of social, economic and spatial indicators (Hertveldt et al., 2009). In addition, the Federal Planning bureau has carried out long term projections on demographic indicators (until 2060), in the framework of a study on the problem of our ageing population (Federaal Planbureau en Algemene Directie Statistiek en Economische Informatie, 2008). Further, literature is reviewed to understand the driving forces of socio-economic change and social, economic and ecological vulnerability. Based on these findings, we have quantified two scenarios:

1. the mean scenario, which is based on prevailing prospects (till 2030-2040) and further extrapolations towards 2100 based on mean values;

2. the maximum scenario, which illustrates a more vulnerable society than the prospects; based on prevailing prospects (till 2030-2040) and further extrapolations towards 2100 using linear or logarithmic regressions (> mean values).

The time horizon used is 2005 – 2040 – 2100, corresponding with the time horizon as defined for the CLIMAR climate change scenarios.

2.3.2.3 Quantifying the secondary impacts

2.3.2.3.1 General

The quantification step as described in the methodological part (indicator approach) can be distinguished in the quantification 1) of the current status, 2) of the climate change impact, based on the climate change scenarios, and 3) of the added impact due to the most important socio-economic parameters.

The selection of the indicators and the quantification of their current status has been based on existing (monitoring) programs. Besides, new indicators have been developed within the scope of CLIMAR.

Indicators have been worked out for the most significant climate risks and described in an Indicator Fact Sheet (IFS) addressing following issues: definition, policy relevance, methodological description, data availability and organizations involved in the development of the indicator. The quantification of the secondary effects (SE) per sector has then been the result of three steps:

- Current status: The quantification of the selected indicators based on the most recent available data. Roughly spoken this relates to the “Elements at risk” factor of the SE within the described indicator approach;
- Climate change impact: The relation of the primary effects (linked with the climate change scenarios) and the secondary effects (selected indicators) has been described. Due to time limitations, the resulting main impact has been quantified for two of the climate change scenarios, *i.e.*, M+ 2040 and WCS 2100; for the coastal defence study, some additional scenarios are used.
- Added impact: As mentioned before, next to the climate change scenarios, socio-economic scenarios (both mid and long-term) have been considered in order to quantify the added impact due to the most important socio-economic parameters. Socio-economic (external) factors can both influence the “elements at risk” (*e.g.*, population growth will lead to more people at risk) and the vulnerability to a certain climate risk (*e.g.*, increased fuel price will worsen economical impact on fisheries).

2.3.2.3.2 Case study of coastal flooding

The most important indicators, selected to be quantified as indicators for the risks of climate change related to coastal flooding, are listed in Table IV.

Table IV: Selected main risks and their indicators for the case study coastal flooding

Effect category	Effect	Direct/ Indirect	Related to	Indicator
Ecological – Habitat change	Change in beach and dune area	Direct	State of sea defence, beach tourism, ecotourism	% change of beach area per municipality /year
Economical – Damage costs	Damages due to flooding	Direct	Flooding, coastal erosion	Damage model
Social – Safety	Casualties	Direct	Sea level rise, increased storminess	Casualties model

Within the scope of the CLIMAR project, these indicators are quantified by means of different numerical and GIS models. Due to the time-consuming risk calculations only two climate change scenarios with two time horizons (2040, 2100) are considered within the case study coastal flooding. In addition to the present day status; the M+ scenario, representing the minimum scenario of climate change, and the worst case scenario (WCS). However, the quantification results of the effects in the other scenarios are expected not to differ substantially from the considered scenarios.

The indicator "habitat loss" is described as the percentage of the total beach area that is lost due to mean sea level rise in the different scenarios of climate change, given per municipality. The total loss of beach area due to sea level rise can be estimated by calculating the area between low-water level (+1.39 m TAW) and dune foot or dike for each climate scenario by 2040/2100.

Table V gives an overview per municipality of the total beach area expected to be lost due to sea level rise. An average loss of 17 % beach area can be expected for the entire coastline in the M+ climate scenario by 2100, while in the worst case climate scenario an average loss of almost 50 % of the Belgian beach area is calculated.

The damage costs and number of victims due to flooding are quantified by means of a methodology based on the risk assessment methodology developed by Flanders Hydraulics in the scope of the European project SAFECOAST (Verwaest et al., 2008a). The method is detailed in Van der Biest et al. (2009a). Each scenario of climate change is statistically translated into a worst credible storm event with an associated return period of 1/17000 years (Verwaest et al., 2008b). A storm with return period 1/17000 yr and present-day sea level and wave climate corresponds to a storm surge level of +8 m TAW in Oostende. Through hydrodynamic, hydraulic and risk modelling, damage and victims resulting from this storm event are calculated. The results are listed in Table VI.

Table V: Available surface area of supra- and intertidal beach in km², and % change of beach area per coastal community due to sea level rise for present day (2006) and under different climate change scenarios.

Municipality	Present	2040 M+		2040 WCS		2100 M+		2100 WCS	
	Beach	Beach	Loss	Beach	Loss	Beach	Loss	Beach	Loss
De Panne	1.53	1.35	12	1.26	18	1.25	19	0.75	51
Koksijde	2.70	2.51	7	2.38	12	2.20	18	1.39	49
Nieuwpoort	1.06	0.97	8	0.92	14	0.89	17	0.53	50
Middelkerke	1.64	1.52	8	1.42	14	1.38	16	0.73	55
Oostende	1.55	1.38	11	1.29	17	1.25	19	0.62	60
Bredene	0.84	0.75	10	0.72	14	0.70	17	0.45	47
De Haan	2.64	2.31	13	2.20	17	2.15	19	1.37	48
Blankenberge	0.82	0.76	7	0.72	12	0.69	17	0.43	47
Zeebrugge	1.02	0.97	5	0.94	8	0.89	13	0.66	35
Knokke-Heist	2.69	2.54	6	2.41	10	2.37	12	1.62	40
Average			9		14		17		48

Table VI: Damage and victims resulting from a worst credible storm event for present day (2006) and under different climate change scenarios.

	Present	2040 M+	2040 WCS	2100 M+	2100 WCS
Damage (10^9 €)	0.58	2.33	3.21	3.49	16.02
Victims	11	177	254	322	4334

Under present climate conditions, 3 weak points in the natural sea defence are identified: Mariakerke, the centre of Oostende and Wenduine. An extreme storm reveals to cause breaches in the sea defence only near cities. At these locations the natural sea wall (dunes) is lowered for the construction of buildings and roads. The flood zone is confined to low-lying areas. The area with highest flood damage costs is found at Oostende. The risks are higher due to the concentration of buildings and population in the city. The total damage cost is estimated at 5.8 10^8 **€**, while the number of victims is estimated around 11.

In the M+ scenario by 2040 breaches are expected to occur mainly off seaside resorts (Mariakerke-Oostende, Wenduine, Blankenberge) but also at dune passages. The total damage cost is estimated at 2.3 10^9 **€**, while the number of victims is estimated around 177.

In the WCS 2040 scenario breaches are expected to occur mainly off seaside resorts (Mariakerke-Oostende, Wenduine, Blankenberge, Heist) but also at dune passages. The total damage cost is estimated at 3.2 10^9 **€**, while the number of victims is estimated around 254.

In the M+ scenario by 2100 breaches are expected to occur mainly off seaside resorts but also at dune passages. The greatest risk associated with flooding and damages to infrastructure arises near the breaches themselves, due to the momentum of the inflowing sea water. The total damage cost is estimated at 3.5 10^9 **€**, while the number of victims is estimated around 320.

For the WCS 2100 scenario, breaches resulting from backshore erosion occur in more then 50 % of the profiles. In some cases the crest of the sea defence is lower then the storm surge level even without taking erosion into account. This is the case for a majority of the beach towns, except for Koksijde, Nieuwpoort, Westende, Bredene (besides a few dune passages) and De Haan. The total damage cost is estimated at 16 10^9 **€**, while the number of victims is estimated around 4300.

Ports are not taken into account within the flood risk calculations. They are considered a separate issue requiring different types of models.

2.3.2.3.3 Case study fisheries

Figure 11 shows a schematic overview of the effect categories, identified secondary effects relevant for the Belgian fishing fleet and possible indicators. Based on the priority score (as described under methodology) it was decided to focus on the combined ecological effects, due to the complexity of the ecosystem and interactions between the different components, using the indicator 'Size, composition and geographical distribution of fish stocks'. This indicator is directly linked to the production, *e.g.*, 'catch' and therefore 'income of ship owners' and 'income fisherman'. 'Number of jobs' is related to the profitability of the fleet, vessel size and fishing method. 'Days at sea/accessibility of fishing grounds' and the 'risk for vessel and crew' are linked to storminess and (extreme) weather conditions.

A vital step in quantifying the ecological and associated economical and social effects of climate change on the Belgian fleet is predicting the change in size, composition and geographical distribution of (potential) commercial fish stock. Marine fish populations are often large, have the opportunity to migration, have a high fecundity, different life stages, can be benthic or pelagic, and show natural fluctuations in stock status and year class strength. Population persistence depends on life cycle closure and the availability of suitable habitats. Regional differences in the spatial and temporal extent of suitable habitats, population regulation and biological interactions among organisms (*e.g.*, predation and competition) may lead to population specific effects of climate change in a species. As the differences in life history traits and responses of vital rates (*e.g.*, growth mortality and reproduction) and physiology (bioenergetics) to abiotic and biotic factors the effects of climate change will be species specific (Tulp et al., 2006).

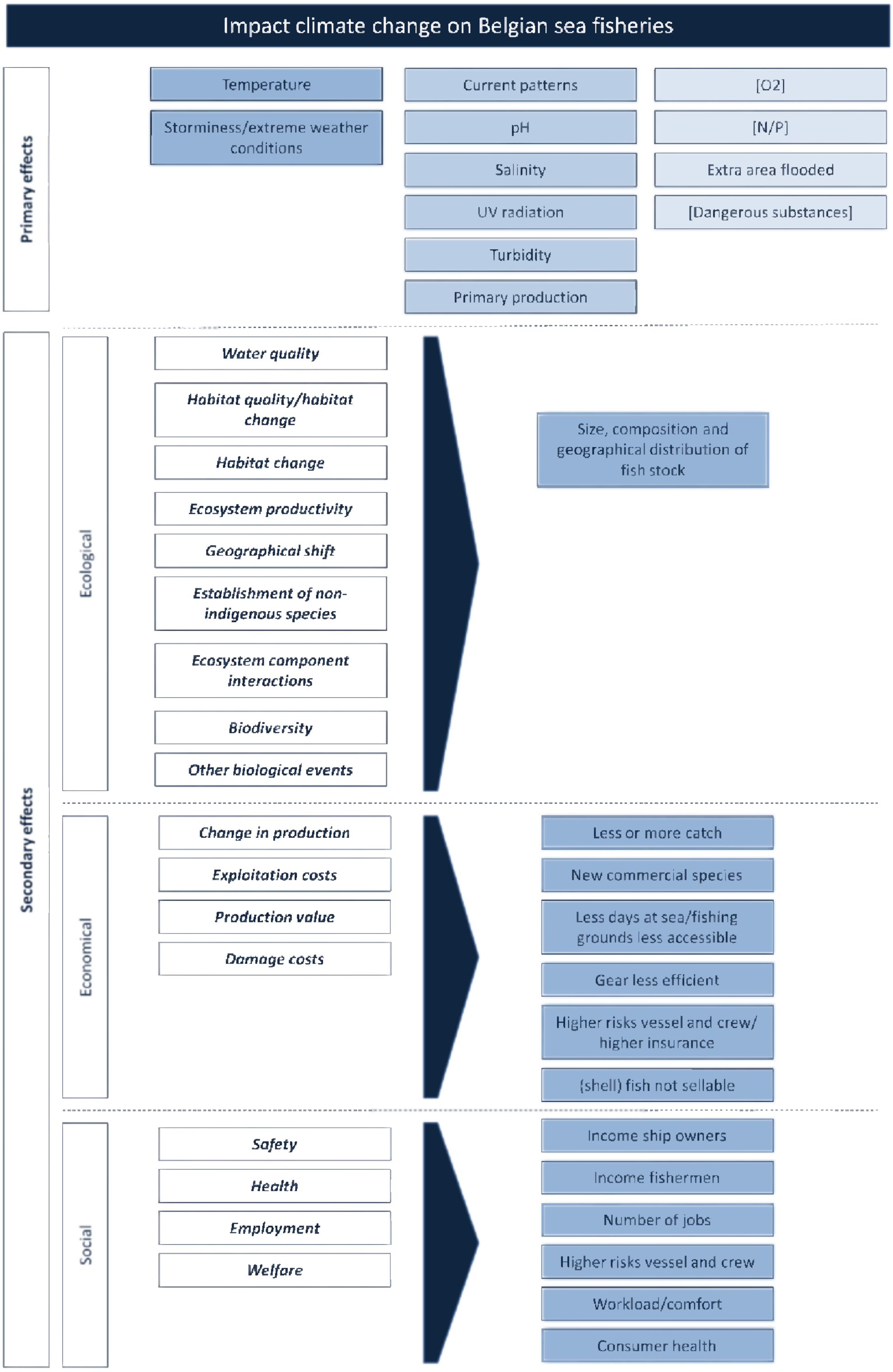


Figure 11: Schematic overview of the effect categories and identified secondary effects relevant for the Belgian fishing fleet and possible indicators.

In contrast with the other partners, ILVO-Fisheries is not only focusing on the BPNS but compiled additional information, when relevant, on climate change effects for areas in which the fleet is active (see 2.3.2.1.2).

A study from Perry et al. (2005) shows that the distribution of both exploited and non exploited North Sea fishes have responded markedly to recent increases in sea temperature, with nearly two-third of species shifting in mean latitude or depth or both over 25 years. For species with northerly or southerly range margins in the North Sea, have shown boundary shifts with warming, and all but one shifted northwards. Species with shifting distributions have faster life cycles and smaller body sizes than non-shifting species.

A more recent study, using ecotypes, shows that many demersal and pelagic species changed abundance and distribution in all OSPAR regions (Tasker, 2008). Many of these changes were in accordance with what can be expected from climate change. Two changes in distribution were apparent: a shift along the depth gradient and latitudinal shift. The whole North Sea fish assemblage has deepened (Dulvy et al., 2008) ~3.6 m per decade in response to climate change, and the deepening is coherent for most assemblage. The latitudinal response to warming seas is more heterogeneous and is a composite of at least two patterns (Tasker, 2008): (1) A northward shift in the average latitude of abundant, widespread specialists (*e.g.*, grey gurnard and poor cod); (2) A southward shift of relatively small, abundant species with limited occupancy and northern range boundary in the North Sea (*e.g.*, sole, bib, solenette and lesser spotted dogfish). The southward shift of warm-tolerant species in the North Sea is consistent with climate change acting trough: (1) The warming and increased availability of shallow habitats in the southern North Sea; (2) The NAO-linked inflows of warm water into north-eastern North Sea.

The spatial distribution and/or recruitment of species important for the Belgian fisheries like sole (Rijnsdorp, 2010), plaice (Perry et al., 2005; van Keeken et al., 2007) and cod (ICES, 2002) were already affected by climate change. More southern commercial species, like red mullet and John Dory, which are currently not important for Belgian fisheries but have a high economic value and are still quota free species, are likely to increase their northerly presence in response to climatic warming (Engelhard et al., 2008). Further temperature rises are likely to have profound impacts on commercial fisheries through continued shifts in distribution and alterations in community interaction (ICES, 2008a; Perry et al., 2005).

Explaining historical changes in storminess and extreme weather conditions remains very difficult, even using historic comprehensive datasets (see 2.2.2.3.2). Bad weather conditions can hamper the work on board of a fishing vessel and increase the risk for crew members and vessel. Not only the wind speed but also the wind direction, type of vessel and the fishing method used determine the possible risk for crew and vessel.

In principle large beam trawlers can leave port under almost every weather condition. Smaller coastal vessels can still fish when the wind speed rise to 5 Beaufort (Fresh breeze), or even 6 Beaufort (Strong breeze) when the wind is blowing offshore. Eurocutters (small fleet segment, max length 24m) stay in the harbor at 7 to 8 Beaufort (Moderate gale to gale). Taking in account the uncertainties illustrated above it was opted not to quantify the impact of a change in the intensity and frequency of storms.

However, adaptation measures where identified and included in the multi-criteria analyses and survey conducted later on (Vanderperren et al., 2011b).

More details on climate change impacts affecting Belgian sea fisheries are available in a separate report (Vanderperren et al., 2011a).

2.3.2.3.4 Case study coastal tourism

Based on the priority score (as described under methodology) the following risks and their indicators were selected for the sector Tourism (Table VII). These are further discussed in detail in Volckaert and De Sutter (2009).

Table VII: Selected main risks and their indicators (Sector Tourism)

Effect category	Effect	Direct / Indirect	Related to	Indicator
Ecological - Habitat Change	Coastal erosion (loss of beach and dune area)	Direct	Beach tourism Ecotourism	% or surface of recreational beach area that is eroding
Ecological - Geographical Shift	Increase of sea mammals	Direct/ Indirect	Ecotourism	# sea mammals observed in the Belgian marine waters
Social - Attractiveness	Attraction value coast	Direct	All sectors	Coastal Climate Index
Social – Accessibility	Accessibility coast by road or public transport	Indirect	All sectors	cost of travel time = f(travel intensity, damage coastal infrastructure)
Social/Economical – Safety/ damage costs	Loss/ damage to marina's, accommodations	Direct	Water tourism Commercial tourism	Loss or damage to berths and moorings for recreational boating expressed as maintenance cost marinas
Economical – Economic result	Turnover of tourism sector	Indirect	All sectors (focus on commercial tourism)	Overall turnover tourism sector (incl. new commercial activities)

2.4 DECISION MAKING AND ACTION PLANNING (ADAPTATION)

Adaptation is a process by which strategies aiming to moderate, cope with, and take advantage of the consequences of climate events are enhanced, developed and implemented. A climate adaptation strategy represents a combination of measures and options chosen to meet a particular risk.

2.4.1 Identification of adaptation measures

2.4.1.1 Typology

Following the precautionary principle, numerous adaptation measures, both structural and non-structural, are being developed in Belgium. In order to structure the possible portfolio of measures to be considered the following typology, developed in phase 1, was used within CLIMAR: Share loss, Bear loss, Prevent the effects: Structural and technological, Prevent the effects: Legislative, regulatory, institutional, Avoid changes, Exploit opportunities, Research, Education and communication, Behavioural change.

Examples are given further in the sectoral adaptation strategies.

The selected adaptation measures are described using a standardized format: the Adaptation Measure Fact Sheet (AMFS) including:

1) Definition of the adaptation measure
2) Classification
3) Possible side effects
4) Investment and operating costs
5) Policy Relevance
6) Implementation

The identification of the adaptation measures will be the result of available literature, expert knowledge and participatory approach (workshops). For each of the three case studies (coastal flooding, fisheries, coastal tourism), a workshop has taken place.

2.4.1.2 Pre-assessment of the adaptation measures

A multi-criteria analysis (pre-MCA) has been executed to select (first screening) the most efficient measures as basic input for the adaptation strategy. The ranking of the adaptation measures has occurred by using the following score-table for the identified evaluation criteria (Table VIII). The score-table is based on a semi-quantitative scale giving higher values to more effective options. Finally, each of the criteria has been given a weight as a function of their importance (equal versus unequal weighting).

2.4.1.3 Case study coastal defence

The development and pre-assessment of the adaptation measures is based on literature review and on stakeholder involvement through an interactive multisectoral workshop (Table IX). In total 9 possible adaptation measures have been identified for the coastal protection case study, for which an adaptation measure fact sheet (AMFS) was developed. The measures are projected onto the Belgian coastline. Composite maps of land use and flood risk are used to define which type of defence measure is most feasible for every specific coastal region in Belgium and to identify possible conflicts between alternative defence measures and land use developments. More information on the measures and their projection onto the Belgian coastline can be found in Van der Biest et al. (2009b). The dimensioning of the measures for the different climate change scenarios is described by Reyns et al. (2011).

Table VIII: Score-table pre-MCA analysis CLIMAR

Score	0	1	3	5
Adaptation typology	Share loss or Bear loss	Avoid changes	Prevent (technical, regulatory)	Exploit opportunities
Importance (~effect reduction)	Very low (failure risk reduction irrespective cost)	Low (moderate effect reduction; low to medium policy support)	Medium to high (cope with effect; medium to high policy support)	Very high (take advantages? Extra benefits)
Technical feasibility	Very complex (100% fixed; no experience; very high risk)	Complex (100% fixed; few experience; large scale and/or “all or nothing”)	Moderate complex (> 50% fixed; medium to large experience; small scale and/or gradual implementation)	Hardly complex (> 50% flexible, few/large experience; adaptive)
No-regret measures	Affect directly the liveability of a sector; very low net benefits	Low net benefits	Medium to high net benefits	Very high net benefits
Ecosystem approach	No interrelationship	Both ecological socio-economical, emphasis on ecological aspect	Both ecological socio-economical, emphasis on socio-economical aspect	Both ecological socio-economical, in balanced way
Multi-sectoral character of measures	Significantly negatively influencing on other sector(s)	Possibly slightly negatively influencing on other sector(s)	Neutral or no influence on other sector(s)	Overall positively influencing other sector(s)
Urgency	Very high level of urgency	Medium to high level of urgency	Low level of urgency	Very low level of urgency
Institutional complexity	Realizing the option requires radical institutional changes and/or the legal procedure will take a long time period	Realizing the option requires substantial institutional changes and/or the legal procedure will take a long time period	Realizing the option requires some institutional changes which can be made in a short period and/or the legal procedure can be finished in a short period	Realizing the option requires no institutional changes and/or the legal procedure can be finished in a short period

A pre-MCA analysis has been performed on these measures. The adaptation measures have further been ranked based on the calculated score. Three classes (ranking) were identified: low (orange), medium (green) and high (blue) potential on success.

Table IX: Overview of possible climate change adaptation measures for coastal protection

Adaptation type	Adaptation measure
Share loss	Adapted insurance formula for people living in flood risk zones
Bear loss	Allow the sea to retreat inland in a controlled way. Relocate towns inland and abandon sea side.
Prevent the effects, structural and technological	Construction of artificial islands in front of the coast to attenuate wave impact
	A dike so solid (broad and/or high) that it can not breach nor overflow during a super storm
	Mega-nourishments to create very large beaches to reduce wave impact and to prevent flooding
	Floating breakwaters in front of the coast to attenuate wave impact
	Make ground floor water proof by relocating valuable good to upper floors. Adapting building standards to make buildings water-proof
Prevent the effects: legislative, regulatory, institutional	Up-to-date strategy plans what to do in case of emergency (effective alert, evacuation routes, places of shelter...)
	Communication to the broad public to make the people aware of the risk of living in certain areas and make them responsible for themselves

Two options have been worked out (Table X):

- Unequal weights: the evaluation criteria “Importance”, “Technical feasibility”, “Ecosystem approach” and “Multisectoral” receiving a score of 3, while the other criteria received a score of 1;
- Equal weights: all evaluation criteria have an equal weight (of 2).

The differentiation in weighting did not result in a different ranking of adaptation measures. Based on the MCA analysis large-scale managed retreat (C05) is not withheld as a viable alternative. Super dikes (C03) and very large beaches (C04) have an excellent potential for success. Artificial islands (C01) is also incorporated in the adaptation strategies. Breakwaters (C02), evacuation planning (C06), climate-proof building (C07), flood insurance (C08) and risk communication (C09) are not considered as part of the adaptation strategies because they were ranked inferior. An additional alternative (C10) is added, namely a combination of sand nourishments and dike heightening, which is a combination of the highest-ranked measures super dikes (C03) and very large beaches (C04).

The MCA is elaborated in more detail in Reyns et al. (2011).

Table X: Ranking of adaptation measures according to pre-assessment by MCA

Code	Measure	Equal weight	Unequal weight
C01	Artificial islands	4	4
C02	Breakwaters	5	5
C03	Super dike	1	1
C04	Very large beaches	2	2
C05	Lange-scale managed retreat	10	10
C06	Contingency plans	6	6
C07	Climate-proof building	7	7
C08	Flood insurance	9	9
C09	Risk maps	8	8
C10	Dike and nourishments	3	3

2.4.1.4 Case study fisheries

2.4.1.4.1 Introduction

Variability on a range of time-scales has always been a feature of fisheries, especially capture fisheries. Where there is effective management in place, fisheries systems have developed adaptive strategies and through monitoring and feedback, fishing effort and catches are regularly modified according the state of the stock. In these cases, the fishing community must have either the robustness or flexibility (or both) to absorb the changes in resource abundance so as to avoid negative ecological, social or economical impacts. Robustness is typically associated with factors such as total fishing capacity being commensurate with the productive capacity of the resource during its lower productivity phases, the availability of alternative fishing resources, investments in flexible technologies such as multipurpose boats (as opposed to specialised vessels) and flexible processing chains, or the ability and opportunity to alternative livelihoods during lean periods (Food and Agriculture Organisation, 2007).

The response of fishing communities to global changes can differ (Perry et al., 2009). Several studies illustrate the general statement that resource-dependent communities seek to increase their adaptive capacity through flexibility in the human subsystem that enables responses to significant changes in the natural subsystem.

- At a short term scale, fishing can be intensified, target species and fishing method can be diversified, or the fleet can decide to ‘hibernate’. These measures/strategies can be considered as a coping measure/strategy.

- At longer time scales the implementation of adaptation measures/strategy can be considered. The fleet/fishing community can change to other fisheries, upgrade its skill and/or education, improve their networking, opt for another industry, political action or decide to terminate its activities.

The identified adaptation measures contribute to the development of the fishing industry into a sustainable activity and enable in varying ways the fishing sector to counter act or benefit from the effects of climate change.

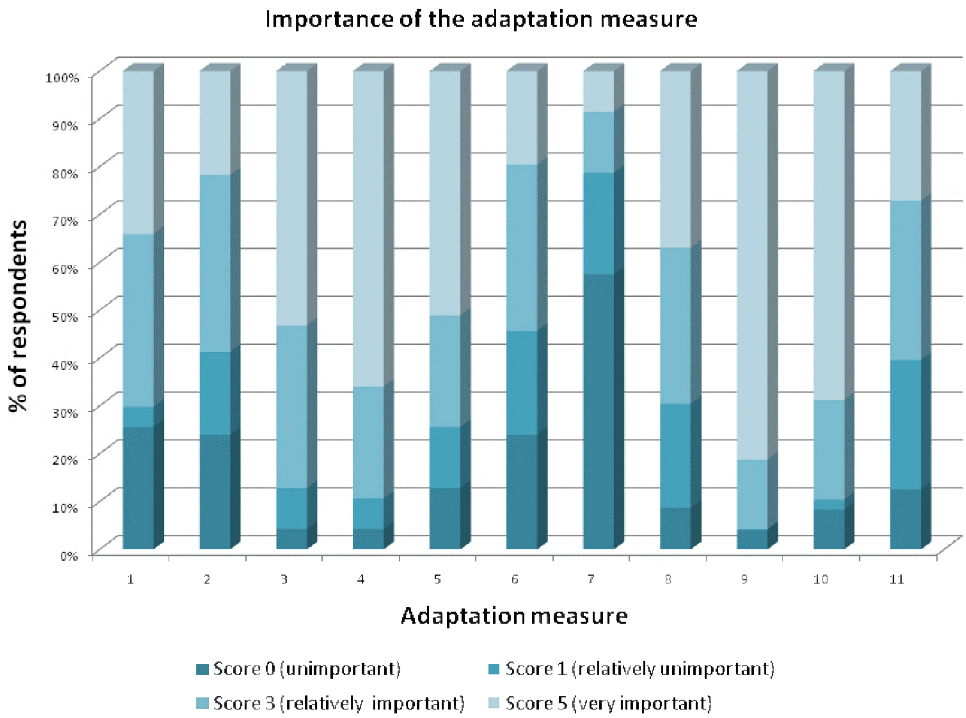
2.4.1.4.2 Identification of measures

Table XI lists the adaptation measures identified for the fisheries case study. As described earlier several drivers, which are not climate change related, are affecting or threatening the functioning and profitability of the Belgian fleet. As a consequence, although the research was conducted from a climate change perspective, this is reflected in the identified measures.

Table XI: Typology of possible adaptation measures for the fisheries sector

Adaptation type	Adaptation measure
Bear loss	Divert to other fishing grounds (follow fish)
Exploit new opportunities	Change target species - Exploit new/other stocks
Prevent effects: Structural and technological	Change fishing techniques - initiative ship owner
Prevent effects: Legislative, regulatory, institutional	Change fishing techniques/fleet structure - initiative policy
Prevent effects: Legislative, regulatory, institutional	Implement flexible fisheries management
Prevent effects: Legislative, regulatory, institutional	Introduction ecosystem management
Share loss	Decrease sea fisheries fleet
Research	Examine the effects of climate change on the marine environment/fish species
Education and communication	Improve communication fisheries sector/scientists/policy
Prevent effects: Structural and technological	Improve safety onboard vessel - initiative ship owner
Education and communication	Government imposes additional safety measures
Exploit new opportunities	Find new markets
Exploit new opportunities	Create product added value
Exploit new opportunities	Ecolabelling/certification/promotion

An MCA was conducted scoring these measures on the criteria defined in Table VIII At first the analysis for ranking the different measures was performed using equal weights for the evaluation criteria. Subsequently, this analysis was performed using unequal weights: adaptation typology = 1, importance = 4, technical feasibility = 3, no-regret measures = 0, ecosystem approach = 3, multi-sectoral = 2, urgency = 1, Institutional complexity = 1. 'Importance', 'technical feasibility' and the 'ecosystem approach' were considered as the most relevant criteria and weighted accordingly. To maximise the stakeholder participation and to generate feedback people active in the fishing industry are questioned on the importance and the feasibility of the proposed adaptation measures. During a workshop organised by ILVO-Fisheries, December 2010, and at the occasion of numerous visits to fishing vessels 48 questionnaires were collected. The results of these responses were used to underpin the score for the criteria 'importance' and '(technical) feasibility' of the adaptation measures. Figure 12 the scores for importance and feasibility of proposed adaptation measures for the Belgian sea fisheries sector as percentage of respondents (48 respondents, mainly (seagoing) ship owners fishing with (adapted) beam trawls).



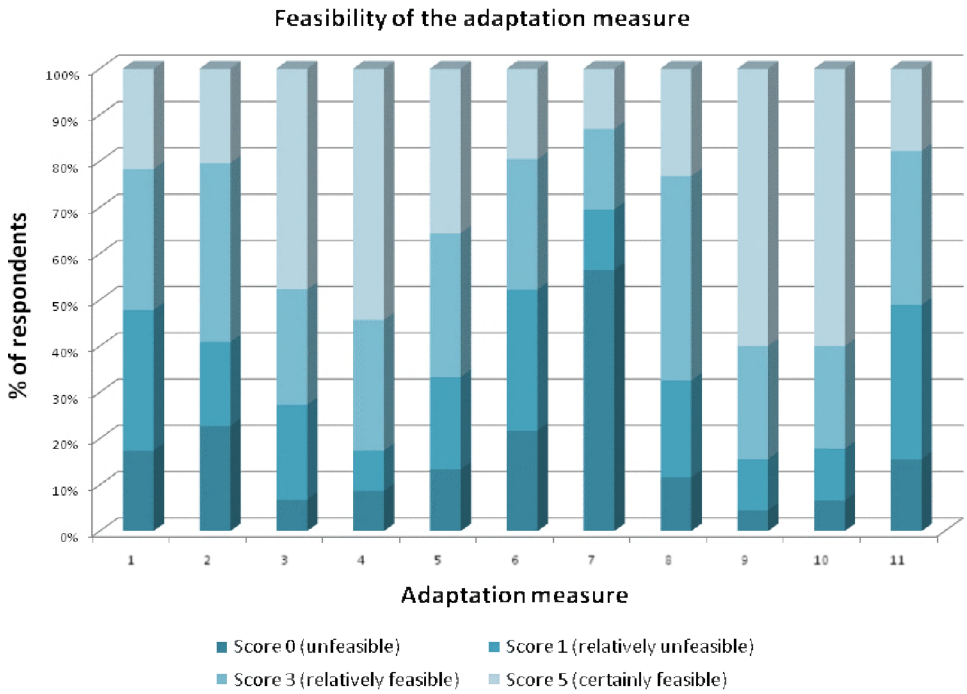


Figure 12: Survey results - 'Importance' and 'feasibility' of proposed adaptation measures for the Belgian sea fisheries sector (score as percentage of respondents).

The ranking of the adaptation measures using equal and unequal weights are presented in Table XII. The adaptation measures have low (orange), medium (green) and high (blue) potential on success.

Table XII: Ranking of the adaptation measures fisheries sector

Nr°	Adaptation measure	Equal weights	Unequal weights
F01	Divert to other fishing grounds (follow fish)	12	7
F02	Change target species - Exploit new/other stocks	1	5
F03	Change fishing techniques - initiative ship owner	1	2
F04	Change fishing techniques/fleet structure - initiative policy	1	2
F05	Implement flexible fisheries management	10	2
F06	Introduction ecosystem management	10	9
F07	Decrease sea fisheries fleet	14	14
F08	Examine the effects of climate change on the marine environment/fish species	8	5
F09	Improve communication fisheries sector/scientists/policy	9	8
F10	Improve safety onboard vessel - initiative ship owner	4	1
F11	Government imposes additional safety measures	12	13
F12	Find new markets	4	9
F13	Create product added value	4	9
F14	Ecolabelling/certification/promotion (sustainability and quality)	4	9

The ranking of the measures using unequal weights was considered to select the adaptations measures for the identification of adaptation strategies. All measures scoring 50 or more, *i.e.*, the first 8 ranked, were selected, as well as measure F06 'Introduction ecosystem management' as this will be implemented in the near future. Although measure F07 has a very low score, it will be included because it reflects the vision of the European Commission. If in a later phase of the analyses this measure proves to be irrelevant in a Belgian context, as the fishing industry believes the minimum critical threshold for our fleet is reached, the analyses will focus more on the other measures. F08 and F09 were excluded as the adaptation types 'Research' and 'Education & communication' were in the final methodology not considered as a separate measure. F10 was excluded as the impact of a change in intensity and frequency of storms was not quantified (Vanderperren et al., 2011a). Concluding, the adaptation measures F01, F02, F03, F04, F05, F06 and F07 are combined as sectoral adaptation strategies.

Guidance and (financial) assistance from policy makers throughout the adaptation process should aim at mitigating the negative effects of climate change and help to make the most of the opportunities offered. In principle these measure/strategies can be developed on a global, European, national, regional or even individual level.

Most commercial fish stocks are managed based on the advice given by the ICES working groups which use the ICES areas as geographical and biological reference. Stocks important for Belgian fisheries are exploited by several countries, based on the quota assigned by the European Commission. As a consequence, the majority of regulations affecting the Belgian fleet are issued by the European Commission, leaving not much room for national policy makers to implement own regulations which could support adaptation strategies.

In a Belgian context these adaptation strategies will act by changing the operational functioning and structure of the fleet. ILVO-Fisheries compiled data on alternative fishing methods (economic, technical, impact), applicable of these methods in the Belgian context, ICES advice and quota evolution as input for the development of adaptation strategies. Data on the evolution of fuel and fish prices were collected to work out socio-economic scenarios relevant for the fisheries sector.

More information is available in the report focussing on the development and evaluation of adaptation strategies to climate change impacts affecting Belgian fisheries (Vanderperren et al., 2011b).

2.4.1.5 Case study coastal tourism

2.4.1.5.1 Introduction

All tourism businesses and destinations will need to adapt in order to minimize risks and capitalize on new opportunities in a sustainable way.

Available studies that have examined the climate change risk appraisal of tourism operators have consistently found low awareness of climate change and little evidence of long-term strategic planning in anticipation of future changes in climate (Simpson et al., 2008).

The increasing, new climate related risks to health, availability of water, energy demand and infrastructure are likely to be dealt with through efficient cooperation with local governments. Another adaptive measure for European tourism, in general, is promoting new forms of tourism such as ecotourism or cultural tourism and placing greater emphasis on man-made rather than natural attractions, which are less sensitive to weather conditions. It is also likely that people will adapt autonomously and reactively by changing their recreation and travel behaviour in response to the new climatic conditions.

2.4.1.5.2 Identification of measures

Table XIII gives an overview of possible adaptation measures for the tourism sector at the Belgian coast.

Table XIII: Typology of possible adaptation measures for the tourism sector at the Belgian coast

Adaptation type	Description Examples of measures for tourism
Share loss	Install a tourist climate change contribution for overnight stays to raise funding for climate change effects or installing adaptation measures (e.g., for beach nourishment). Innovative insurance premiums, including “natural risk” effects on business activities. Compensation by government for tourist sector during bad weather days.
Bear loss	Loss of beaches due to sea-level rise and/or increased rates of coastal erosion: need for chronically beach nourishment (this technique is needed for coastal flooding safety, hence the “cost” for tourism could be lower than the “benefit”) Autonomous adaptation: it is possible that people will adapt autonomously and reactively by changing their recreation and travel behaviour in response to the new climatic conditions. Prohibit tourism beach activities during certain periods with increased risk on storminess.
Prevent the effects. Structural and technological	Adapt the tourism facilities in order to accommodate people all year round and buffer the longer drought or severe weather periods being less sensitive to the “vacation period touristic good weather income” (e.g., ecological recreation complex, Woestenburg, 2006). Climate proof (coastal flooding, storminess) building standards for new hotels and other accommodation. Assistance with emergency planning for yachts and other recreational crafts in marinas. Sustainable (drinking) water use program in hotels and other tourism accommodation, accompanied by water resources program.

Adaptation type	Description Examples of measures for tourism
Prevent the effects: Legislative, regulatory, institutional	Bad weather forecasting (on-line) tools. Strategic planning for inland tourism development zones to provide alternatives to coastal tourism land use policies. Spreading of holiday periods. Road pricing.
Avoid changes	Moving tourism infrastructure further back from the coast or move away from specific at higher risk locations
Exploit opportunities	Increasing air and water temperature will lead to more favourable tourism conditions. Possible measures are : zero-option (no measure needed, but more economic welfare due to higher number of tourists), increase tourism capacity (hotels, restaurants, ...); induce new forms of tourism; ...
Research	Not elaborated within CLIMAR
Educational Behavioural	Not elaborated within CLIMAR

Each of these adaptation measures are described using the Adaptation Measure Fact Sheet (AMFS).

In total 16 possible adaptation measures have been identified for the coastal tourism sector for which an adaptation measure fact sheet (AMFS) was developed. A pre-MCA analysis has been performed on these measures. The adaptation measures have further been ranked based on the calculated score. Three classes (ranking) were identified: low (orange), moderate (green) and high (blue) potential on success.

Two options have been worked out (Table XIV):

- Unequal weights: the evaluation criteria “Importance”, “Technical feasibility”, “Ecosystem approach” and “Multisectoral” receiving a score of 3, while the other criteria received a score of 1;
- Equal weights: all evaluation criteria have an equal weight (of 2).

Table XIV: Ranking of the adaptation measures coastal tourism

Code	Adaptation measures	Equal weights	Unequal weights
T01	Tourist climate change contribution	8	6
T02	Innovative insurance premiums	12	12
T03	Compensation bad weather days	10	9
T04	Managed retreat	16	16
T05	Beach nourishment	3	3
T06	All-year-round accommodation	5	7
T07	Climate proof building standards	6	5
T08	Preparedness marinas	2	1
T09	On-line weather forecasting tools	1	2
T10	Strategic planning	13	14
T11	Spreading holiday periods	7	8
T12	Tourism facilities further back from coast	15	15
T13	Seal/ whale watching	9	11
T14	Holiday (multi-use) accommodations on artificial islands at sea	11	10
T15	Zero-option	14	13
T16	Road pricing	4	4

All adaptation measures have been comparably classified in terms of importance in both options (unequal versus equal weights). Based on the MCA we can conclude that on-line weather forecasting tools (T09) and preparedness of marinas (T08) have a very high potential on success. Beach nourishment (T05), road pricing (T16) and all-year-round accommodation (T06) or climate proof building standards (T07) (shared ranking position) complete the top 5 of adaptation measures.

Four measures (T04, T10, T12, T15) will be excluded from further analysis due to their low potential on success. Based on the results of the workshop, T13 (seal/whale watching) will also be excluded as this was not seen as an adaptation measure, but as a potential economical and ecological opportunity.

2.4.2 Identification of adaptation strategies

2.4.2.1 General identification of adaptation strategies

Finally, the measures are combined as (inter)sectoral adaptive strategies. The success of the full strategy depends on numerous factors such as the effectiveness of the measures, the acceptance of the introduction, the potential for benefits that outweigh the costs, the consistency of the measures with other sectoral initiatives, etc.

Four different adaptation strategies ("scenarios") have been defined:

- Business-as-usual scenario (BAU): consisting of the most commonly used adaptation measures, so with the emphasis on bear loss, shear loss and technical measures;

- Adaptive approach (ADAPT): gradual adaptation strategy starting with a common combination of adaptation measures on a short term, but giving the possibility to diversify to a certain direction as more information about, e.g., climate impacts or socio-economic scenarios become available;
- Adaptive approach+ (ADAPT+): essentially the same as ADAPT, but with larger intensity of the measures;
- Reactive approach (REACT): fixed adaptation strategy for mid and long term, with the risk on a 180° switch if new information becomes available.

Considering these adaptation scenarios, the time horizons (2040 – 2100), the climate change scenarios (M/M+, W/W+, WCS), the socio-economic scenarios (Mean, Max) 24 different combinations were possible. It is clear that it is not possible to study and presented all these different combinations.

2.4.2.2 Case study coastal defence

After pre-assessment using MCA, the four different adaptation measures that were selected to be suitable were attributed to one of the four adaptation scenarios BAU, ADAPT, ADAPT+, REACT (Table XV). Artificial islands (C01) were shown not to result in an acceptable safety against flooding in Reyns et al. (2010). Therefore this measure is combined with another measure, namely the most cost-effective measure to strengthen the defences, which is very large beaches (C04).

Table XV: Selected adaptation measures per adaptation scenario for case study coastal flooding. BAU: BAU scenario; AD: ADAPT approach; AD+: ADAPT+ approach: REA: REACT approach

Code	Measure	BAU M+ Mean 2040	AD M+ Mean 2040	AD+ M+ Mean 2040	REA M+ Mean 2040	BAU WCS Max 2100	AD WCS Max 2100	AD+ WCS Max 2100	REA WCS Max 2100
C01	Artificial islands			x				x	
C03	Super dike				x				x
C04	Very large beaches		x	x			x	x	
C10	Dike heightening+ nourishments	x				x			

The costs associated with the implementation of the different schemes are calculated from values provided by the Coastal Division (nourishments), and those found in Dutch literature, where similar studies have been performed (e.g., Hillen et al., 2010).

Table XVI presents the benefits and the investment costs of the four defined adaptation scenarios under different climate and socio-economic change scenarios.

Table XVI: Costs and benefits for the different adaptation measures. BAU: BAU scenario; AD: ADAPT approach; AD+: ADAPT+ approach: REA: REACT approach

	BAU M+ Mean 2040	AD M+ Mean 2040	AD+ M+ Mean 2040	REA M+ Mean 2040	BAU WCS Max 2100	AD WCS Max 2100	AD+ WCS Max 2100	REA WCS Max 2100
Change beach area (%)	2	2	2	-9	17	7	7	-48
Reduce victims	187	187	187	187	4334	4334	4334	4334
Reduce damage (10^9 €)	2.64	2.64	2.64	2.64	1.60	1.60	1.60	1.60
Implementation cost (10^9€)	0.417	0.234	1.416	0.354	1.784	0.628	1.715	1.227

It should be noted that the benefits are calculated from breaching and subsequent inland flooding only. Local damage and victims on the sea dikes, as well as flooding via the coastal harbours, can be important (Vanpoucke et al., 2009). However, these aspects are not considered within the methodology of CLIMAR (Van der Biest et al., 2009b)

2.4.2.3 Case study fisheries

The adaptation measures selected based on the MCA were linked to the scenarios agreed on by all partners. The results are given in Table XVII.

Table XVII: Adaptation measures versus strategies fisheries sector

Nr.	Measure	BAU M+ Mean 2040	ADAPT M+ Mean 2040	BAU WCS Max 2100	ADAPT WCS Max 2100	REACT WCS Max 2100
F01	Divert to other fishing grounds (follow fish)		x		x	
F02	Change target species - Exploit new/other stocks		x		x	
F03	Change fishing techniques - initiative ship owner		x		x	
F04	Change fishing techniques/fleet structure – initiative policy	x		x		
F05	Implement flexible fisheries management	x		x		
F06	Introduction ecosystem management	x		x		
F07	Decrease sea fisheries fleet					x

2.4.2.4 Case study coastal tourism

A classification of the adaptation measures classified as medium to high potential on success (pre-assessment phase) according to these defined adaptation strategies is given in Table XVIII.

Table XVIII: Adaptation measures versus strategies tourism sector. BAU: BAU scenario; AD: ADAPT approach; AD+: ADAPT+ approach: REA: REACT approach

Nr.	Measure	BAU M+ Mean 2040	AD M+ Mean 2040	AD+ M+ Mean 2040	BAU WCS Max 2100	AD WCS Max 2100	REA WCS Max 2100
T01	Tourist climate change contribution			x		x	x
T02	Innovative insurance premiums					x	x
T03	Compensation bad weather days			x			
T05	Beach nourishment	x	x	x	x	x	x
T06	All-year round accommodation			x	x	x	x
T07	Climate proof building standards			x		x	x
T08	Preparedness marinas		x	x		x	x
T09	On-line weather forecasting tools	x	x	x	x	x	x
T11	Spreading holiday periods		x		x		x
T14	Holiday (multi-use) accommodations on artificial islands at sea						x
T16	Road pricing			x		x	x

The majority of measures have been linked to more than one scenario. Important to note here is that the level of implementation can differ according to the scenario. For example for adaptation measure T05 "Beach nourishment" in the BAU scenario will be executed to satisfy the defined safety levels, while in the ADAPT+ scenario a higher intensity of beach nourishment will take place to create an added value for seals (sandbanks as resting places).

2.4.3 Public participation

As for many measures related to sustainable development, the success of the implementation of adaptive strategies will depend on the understanding by the civil society and private organizations of the importance of these strategies. It is, in other words, not sufficient to look at adaptation measures only from a technical perspective of sustainability. Measures that are effective (in terms of reducing risk) in theory, can turn out having a lot of implementation problems due to the lack of social acceptance. It is therefore preferable to involve stakeholders, again at the earliest possible stage, in the process of identifying the problem and the possible adaptive strategies, by different means of participation (e.g., interviews, via workshops, survey).

An interactive workshop has been organized for the three considered coastal sectors within CLIMAR. Some information on these workshops is given in the next sections.

2.4.3.1 "De Kust op maat van het klimaat" /"The coast in agreement with the climate"

The first workshop "De Kust op maat van het klimaat" took place on Thursday 4 December 2008 at the InnovOcean site, Oostende (Belgium). The workshop was organised in cooperation with the "Coördinatiepunt Duurzaam Kustbeheer" and with the "MDK-afdeling Kust" (the administration responsible for the coastal defences). The workshop aimed at bringing together representatives from different coastal sectors and to create an interactive debate on how to deal with the possible impact of climate changes on coastal flood risks and the possible adaptation strategies.

During the morning session the participants were introduced into the world of sea defence and climate change problematic. The afternoon session was set up as an interactive workshop. In a first session, the participants were divided into groups of the same sector. They were asked to put forward alternative ideas to adapt to the effects of climate change on coastal erosion and coastal flood risks. In a second session the groups were reorganized so that each group has at least one representative from each coastal sector. The suggestions from the first session were then presented to the multi-sectoral groups. Each of the participants was asked to express the possible side-effects, positive or negative, of the measure on their sector.

Conclusions

- combination of several measures is expected to be most effective.
- along the Belgian coastline, inland solutions seem to be rather difficult due to the lack of space.
- alternative defence measures seem to offer a lot possibilities for win-win situations with other sectors such as energy, tourism, agriculture, aquaculture,...
- multi-criteria, cost-benefit,... analyses are necessary to evaluate all the possible side-effects and opportunities of the measures.

A report of this workshop is available as a separate document (Belpaeme et al., 2008).

2.4.3.2 "Crisis in de Visserij: Keert klimaat het tij?"/ "Crisis in fisheries: does climate turn the tide?"

The second workshop "Crisis in de Visserij: Keert klimaat het tij?" took place on Tuesday 9 December 2008, ILVO-fisheries, Oostende (Belgium). This workshop dealt with the impact of climate changes on the fisheries sector, future developments in de fisheries sector and the possible adaptation strategies.

The interest in the workshop was high, as 73 participants attended the event, and all the requested stakeholders for the round-table were present. Based on the conducted survey (60 respondents) the participants could be spilt as follows: producers organisation (7%), ship-owners (8%), policy (18%), scientific research institutes (23%), distribution chain (2%), conservation organisation (5%) and other (25%) (blank: 12%).

The work executed in the framework of the project, with the focus on the fisheries sector, was presented by the partners in the morning session. The questions asked by the public showed a genuine interest in the subject.

The afternoon session, moderated by Prof. Frank Maes, started with a round-table with different stakeholders: Departement Landbouw en Visserij (Marc Welvaert), Rederscentrale – Regionale Advies Raad (Emiel H. Brouckaert), Centrale Raad voor het Bedrijfsleven (BRC Visserij) (Manu Desutter), ILVO-Fisheries (Hans Polet), Marine Harvest (Anje Mattheeuws and Bertil Buysse), Natuurpunt (Bart Slabbinck), Stichting voor Duurzame Visserijontwikkeling – Regionale Advies Raad (Luc Corbisier) and Vlaams Instituut voor de Zee (Jan Seys).

Each stakeholder presented his/her organisation and shortly expressed their view on the future of the Belgian fisheries sector, focussing on the effect of climate change and possible adaptation strategies. Subsequently, a constructive discussion addresses the possible impacts of climate change on the fisheries sector, expected developments in the fisheries sector and the development of adaptation strategies.

The preliminary results of a short survey conducted when the participant arrived were presented but not discussed.

Conclusions

The high attendance and constructive discussion between the different stakeholders indicates that the general mentality is changing. Summarised, the following can be concluded:

- The complexity of the Belgian sea fisheries sector and the ecosystem hamper the assessment of the impacts of climate change and the development of adaptation strategies, especially on the long-term.
- The Belgian fisheries fleet has a future, yet diversification and reengineering is needed.
- The ecological, economical and social aspects are equally important for the development of the sea fisheries into a sustainable activity.

A report of this workshop is available as a separate document (Vanderperren et al., 2009b).

2.4.3.3 “Hoe dynamisch is ons kusttoerisme in tijden van klimaatverandering?” / “How dynamic is the coastal tourism during climate changes?”

The third workshop “Hoe dynamisch is ons kusttoerisme in tijden van klimaatverandering?” took place on Thursday 14 October 2010 at the Beach Palace Hotel, Blankenberge (Belgium). The workshop was organised in cooperation with the “MDK-afdeling Kust” (the administration responsible for coastal defence). The objective of the workshop was many folded. First the workshop aimed at informing the coastal stakeholders and especially the tourist sector on the effects of climate change in general and the impacts this will have on the tourist sector in general. Second to gather information by stakeholder participation.

What is the vision of stakeholders towards CLIMAR indicators for coastal tourism, possible adaptation responses and how the coastal socio-economic future might unfold in order to establish socio-economic scenarios.

The intention was to have all main coastal and marine sectors represented in the workshop (120 invitations). However, not all sectors were represented, probably due to an overload of workshops on coastal zone related matters. Best represented was the invited research community. None of the 10 local municipalities were represented. Despite the efforts of the organizing committee towards the tourist sector (39 personal invitations), only 4 people were present. According to other initiatives (conferences, info sessions, etc.), this low attendance of the tourist sector seems to be a general trend.

During the morning session, the public was informed about the current Strategic Policy Plan for Tourism (Westtoer), the relationship between coastal tourism and climate change (B. Amelung) and possible adaptation measures (Arcadis). Besides socio-economic changes and possible future visions were presented (Maritime Institute).

The afternoon session was divided into two sessions. The first session was moderated by Annemie Volckaert and Renaat de Sutter and discussed the probability and importance of tourist values and the importance, feasibility and acceptability of the proposed CLIMAR adaptation measures. The second session was moderated by Marian Willekens and Frank Maes and discussed the certainty and importance of drivers of change in the light of climate change.

Conclusions

- The potential increase of sea mammals and the potential risk to marinas is considered not so important and probable.
- The potential loss of recreational beach area and potential increase of touristic top days are most probably to occur and also most important in terms of tourist values at stake.
- Beach nourishment is believed to be the best strategy to protect the tourist values. This corresponds with the importance of recreational beach area as most important value.
- Road pricing, climate building standards and a specific online weather forecast for the coast will contribute to climate change adaptation.
- The most important identified drivers of change are investing in research and communication of scientific date to the sectors/stakeholders, combined with co-operation to achieve an integrated coastal vision.
- Evaluation of adaptation strategies

2.4.4 General description of the evaluation tool

2.4.4.1 Boundary conditions for the evaluation tool

A climate adaptation strategy represents a combination of measures and options chosen to meet a particular risk (European Environment Agency, 2004). The strategy should increase the robustness of long term (infrastructure) investments, enhance the adaptability of vulnerable natural systems, improve societal awareness and preparedness, increase the flexibility of vulnerable marine activities (e.g., ease of change of activities or locations). The success of the full strategy depends on numerous factors such as the effectiveness of the measures, the acceptance of the introduction, the potential for benefits that outweigh the costs, the consistency of the measures with other sectoral initiatives, etc.

In order to stimulate the abovementioned preconditions for the sectoral adaptation strategies, an evaluation framework has been developed that can assess the value of the scenarios for each specific marine sector. The evaluation tool is based on the principles of sustainable development and scores both economical, ecological and social merits and damages of the adaptation strategy. Hence the adaptation strategies have to undergo a sustainability test.

To develop this framework or evaluation tool, all technical possibilities were explored (Toth, 2000). Integrated assessment should combine, interpret and communicate knowledge from different disciplines. Generally, current assessment techniques only fulfil part of this need. Furthermore when considering climate change impact and reduction, less attention has gone to assessing adaptive strategies while focusing on prevention strategies. Among others, consideration has gone to:

- multi-criteria analysis (MCA) - using indicators of impact and indicators for efficiency of measures;
- (social) cost-benefit analysis (CBA) - valuing all costs and benefits over time on the base of “willingness to pay”;
- cost-effectiveness analysis (CEA) - taken a predetermined objective and seeking a way to accomplish it “as inexpensively as possible”.

2.4.4.2 Overview of the different steps

Based on the practical constraints of some of the tools examined (e.g., Definite) an Excel-application has been chosen for the development of the evaluation tool for CLIMAR. It exists of a combined MCA and CBA analysis tool and integrates the results of the previous work packages: climate change scenarios, socio-economic scenarios, impact analysis and quantification, adaptation strategies. Furthermore, it includes a sensitivity test (Monte Carlo permutation) on both the calculated values and the importance (weight) of the different criteria.

The methodological framework for the tool has been developed consisting of following steps:

- Selection of the different adaptation strategies to be compared. This demands a choice of the accompanying climate change scenario, socio-economic scenarios and time horizon.
- Quantification of the ecological and socio-economical effects based on the indicator approach (WP2).
- Calculation of the avoided risk for the selected adaptation measures of one adaptation strategy combined with specific information about the costs of these adaptation measures. This serves as an input for the criteria of the MCA/CBA analysis. The criteria can both be expressed on a monetary as well as semi-quantitative scale.
- Ranking of the different adaptation strategies/scenarios based on the calculated avoided risk, the costs and the importance (weight) of the different criteria of the model.
- Performing a sensitivity analysis to evaluate the weights of the criteria.
- Performing an uncertainty analysis to evaluate the uncertainty on the calculated impact values.
- Graphical presentation of the results.

2.4.5 Illustration of the evaluation tool

An evaluation tool has been developed for the three case studies coastal defence, fisheries and coastal tourism. The practical implementation of the evaluation tool will be illustrated for three adaptation strategies (BAU, Adapt and Adapt+) for the CLIMAR scenario 2040 (M+/Mean) for the sector coastal tourism. More details can be found in Volckaert and De Sutter (2011a).

2.4.5.1 Selection adaptation strategies

For the identification of the adaptation measures for these strategies, reference is made to section 2.4.2.4. The BAU strategy consists only of beach nourishment and on-line weather forecasting, while the ADAPT strategy also includes prepared marinas and spreading holiday periods. The ADAPT+ strategy comprises a more extensive sets of adaptation measures, including, e.g., limited subtidal extensions (elevation 2 sandbanks) besides beach nourishment, tourist climate change contribution, climate proof building standards and road pricing.

2.4.5.2 Quantification of the ecological and socio-economical effects

The quantification of the ecological and socio-economical effects of these measures have been identified using an indicator approach (Table VII). For more information about the different indicators reference is made to Work Package 2 described in Volckaert and De Sutter (2010).

2.4.5.3 Calculation of the avoided risk and the costs of the adaptation strategies

2.4.5.3.1 Basic decision matrix

The first step of the extended CBA consists in defining the problem. In our case the problem is "What set of measures (adaptation strategy) is best suited to reduce the risk of climate change from a welfare point of view?" On this basis the evaluation criteria are set and the adaptation scenarios are selected that are ought to solve the climate change problem.

The evaluation criteria used are related to the described impacts (indicator approach) (Table VII) and the resulting risk reducing effects the adaptation measures/strategies considered have on society. So, on the one hand there is the avoided risk or created benefits to economic, social and ecological systems, but on the other hand there are the investment and operating costs of the measures of which the strategies are composed.

The economic result has been calculated in terms of change of number of day tourists due to the defined risks (loss of recreational beach, increased number sea mammals, attractiveness, accessibility, safety and damage costs) multiplied by the average expenditure behaviour of a day tourist. For example, loss of recreational beach area will lead to a decrease in day tourists and thus in economic result. The overall gain in economic result is due to the expected increase in day tourists due to better weather prognoses (estimated at about 22.8 million day tourists for 2040 M+).

All this information is uploaded from various assessments, discussed in previous chapters of this report or related coastal tourism sector documents (Volckaert and De Sutter, 2009; 2010) and compiled in one matrix. Table XIX provides the decision matrix for coastal tourism for the scenario CLIMAR 2040 (M+/Mean). Note that the score for "effect of attractiveness coast" all amount to zero, as none of the adaptation measures influence this criterium at the time scale 2040.

All evaluation criteria of the decision matrix that are expressed in the same unit (e.g., euro) can be integrated into one single criterion. The resulting decision matrix is called the basic decision matrix. In this matrix all criteria expressed in monetary terms have been integrated and denominated 'net benefits' (Table XX).

Table XIX: Decision matrix coastal tourism CLIMAR 2040 (M+/Mean). BAU: BAU scenario; AD: ADAPT approach; AD+: ADAPT+ approach.

Criteria Tourism	Unit	Adaptation scenarios		
		2040 - BAU M+ Mean	2040 - AD M+ Mean	2040 - AD+ M+ Mean
Avoided ecological risk (habitat change)	m²	13,445,716	13,445,716	13,445,716
Effect on biodiversity (geographical shift)	# sea mammals	0	0	3,150
Effect on attractiveness coast	# day tourists	0	0	0
Avoided social risk (accessibility)	hr/top day	0	2	9
Avoided flood risk (safety/damage costs)	€	0	22,370,643	29,827,524
Effect on economical result	€	2,058,143,341	2,066,573,356	2,101,470,906
Investment & operating costs	€	249,962,203	133,907,313	403,292,478

Table XX: Basic decision matrix coastal tourism CLIMAR 2040 (M+/Mean). BAU: BAU scenario; AD: ADAPT approach; AD+: ADAPT+ approach.

Criteria tourism	Unit	Adaptation scenario		
		2040 - BAU M+ Mean	2040 - AD M+ Mean	2040 - AD+ M+ Mean
Net benefits	€	1,808,181,138	1,955,036,686	1,728,005,953
Avoided ecological risk (habitat change)	m²	13,445,716	13,445,716	13,445,716
Effect on biodiversity (geographical shift)	# sea mammals	0	0	3,150
Effect on attractiveness coast	# day tourists	0	0	0
Avoided social risk (accessibility)	hr/top day	0	2	9

2.4.5.3.2 Standardisation of the basic decision matrix

Standardisation is used to facilitate the comparison of the adaptation strategies of a particular scenario (*e.g.*, BAU versus ADAPT of CLIMAR 2040 (M+/Mean)) or to compare different adaptation scenarios (*e.g.*, CLIMAR 2040 (M+/Mean) – BAU versus CLIMAR 2040 (Worst/Mean) – BAU) on the basis of the various evaluation criteria.

The order of magnitude of the values attributed to the different evaluation criteria in the basic decision matrix need to be made comparable. Important in this respect is that the relation between the values attributed to the strategies for a given evaluation criteria is not altered.

Various standardisation methods exist, each having specific advantages and drawbacks. In the framework of the analysis of climate change adaptation measures we opt for a 'maximum standardisation' for the criteria expressed on a ratio scale. This means the values are divided by a specific maximum value per criterion. For the criterion 'net benefits' we opt for an 'interval standardisation'. This means the values are derived on the basis of a linear interpolation between a specific minimum and maximum value. The standardised basic decision matrix for coastal tourism is shown in Table XXI.

Table XXI: Standardized basic decision matrix coastal tourism CLIMAR 2040 (M+/Mean).

Criteria tourism	Unit	Adaptation scenario		
		2040 - BAU M+ Mean	2040 - ADAPT M+ Mean	2040 – ADAPT+ M+ Mean
Net benefits		0.92	1.00	0.88
Avoided ecological risk (habitat change)		1.00	1.00	1.00
Effect on biodiversity (geographical shift)		0.00	0.00	1.00
Effect on attractiveness coast		0.00	0.00	0.00
Avoided social risk (accessibility)		0.00	0.20	1.00

2.4.5.3.3 Attributing weights to the effects

In order to arrive at a ranking of the adaptation strategies/scenarios considered weights have to be attributed to all evaluation criteria of the basic decision matrix. The total sum of all weights should equal 1. The weighing of the different evaluation criteria has a significant effect on the results of the assessment. For the results to be policy relevant it is important that the weights correspond to the preferences of the public. Hence, this is the part of the decision making process where stakeholder and decision maker participation is most crucial.

Table XXII: Weights for the different criteria of the basic decision matrix coastal tourism CLIMAR 2040 (M+/Mean)

Criteria Tourism	Weight
Net benefits	0.500
Avoided ecological risk	0.125
Effect on biodiversity maintenance (geographical shift)	0.125
Social effect (attractiveness)	0.125
Social effect (accessibility)	0.125

2.4.5.4 Ranking

The standardised basic decision matrix and the weights are combined. This results in a ranking of the adaptation strategies for the CLIMAR scenario 2040 (M+/Mean). The strategy with the highest score is preferred over the other strategies given the input values (values attributed to the adaptation scenarios per evaluation criterion in the decision matrix and the weights per decision criterion) used and the standardisation carried out. The ranking of the strategies of the coastal tourism scenario CLIMAR 2040 (M+/Mean) is shown in Figure 13.

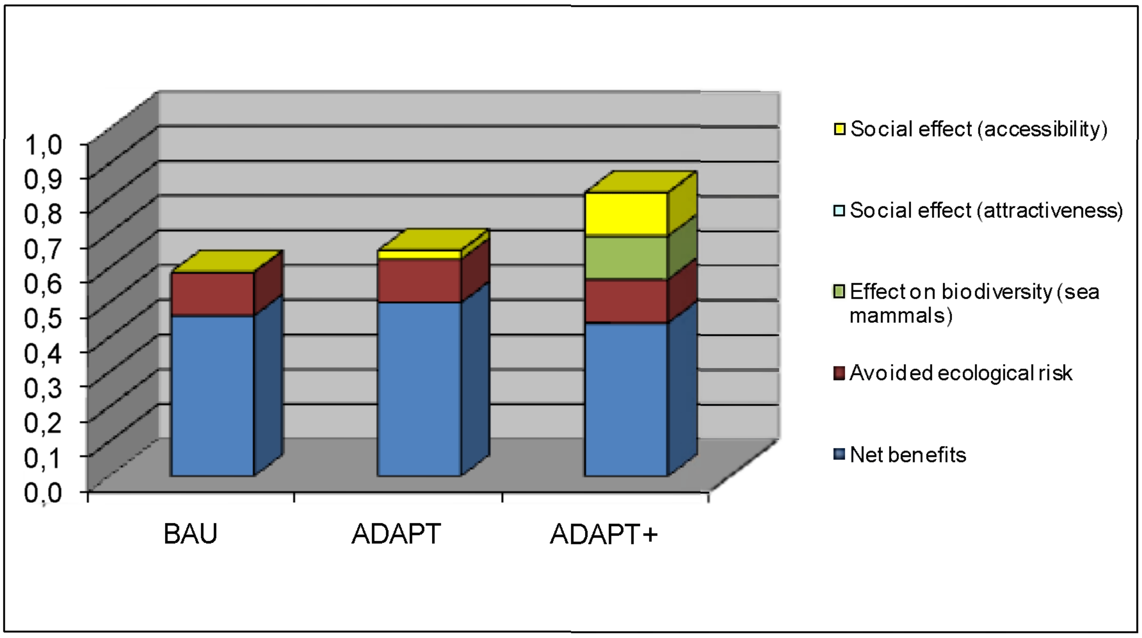


Figure 13: Ranking strategies coastal tourism CLIMAR 2040 (M+/Mean)

The strategy Adapt+ ranks first, followed by the strategy Adapt, with the strategy BAU coming in on the last place. Although these results should be treated with caution and further elaborated, this result does indicate the importance of considering adaptive strategies now in order to solve the adaptation issue, both from an economic as well as from a sustainable point of view.

0

Important to note is that all strategies yield a positive "net benefit". This is probably the consequence of the positive impact of better "touristic weather" conditions attracting more people to our coast. It is clear that this positive situation will not be the case for all sectors.

2.4.5.5 Sensitivity analysis

The ranking of the adaptation strategies/scenarios is reassessed on the basis of a sensitivity analysis. A sensitivity analysis is used for determining the 'critical' parameters/values. The critical parameters are those whose variations, positive or negative, have the greatest impact on a scenarios performance. A sensitivity analysis does not require any information on the uncertainty of any input parameters. Consequently, the resulting information only provides an insight into the robustness/variability of the results.

The decision support model automatically tests the sensitivity of the ranking of the scenarios to changes in the weights attributed to the evaluation criteria of the basic decision matrix. Following this, there is also the possibility to analyse the impact of changes in a specific value of the decision matrix. The need for that kind of analysis could be for instance the result of a discussion with stakeholders on this value of the decision matrix.

Therefore, different runs are carried out in which for each new run a different criterion is given a weight of 0,5 while the others criteria get an equal weight. The net benefits criterion however gets a minimum weight of 0,2857 as economic aspects tend to be given more weight in final decisions. As an example the results of run B (50% avoided ecological risk) and run E (50% accessibility) are presented in Figure 14 and Figure 15.

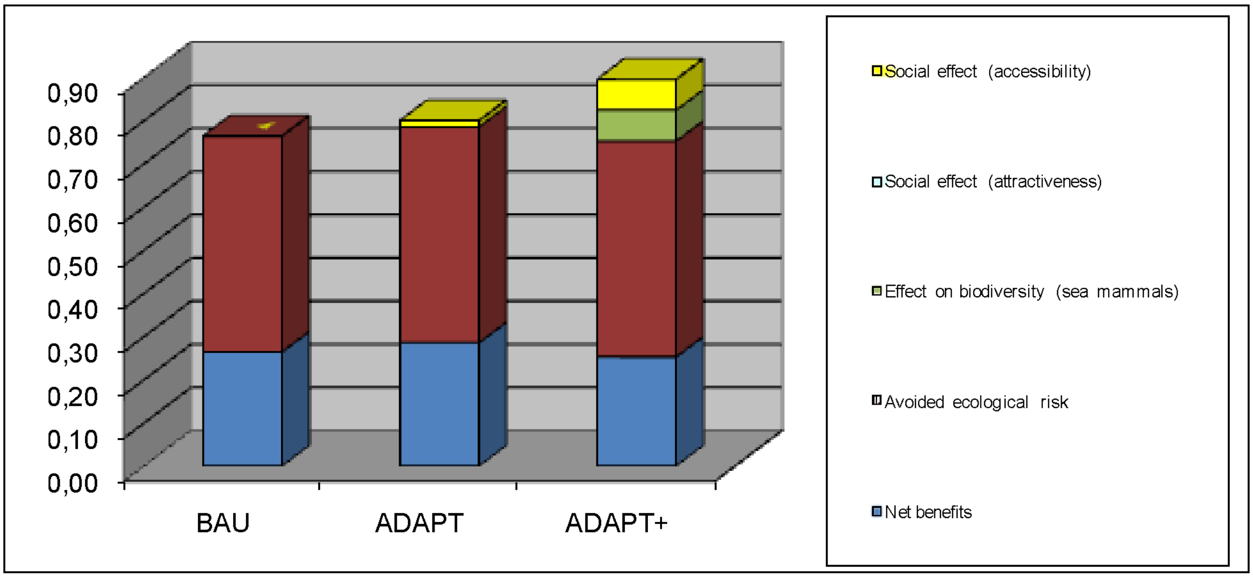


Figure 14: Scores and ranking of the strategies for run B CLIMAR 2040 (M+/Mean)

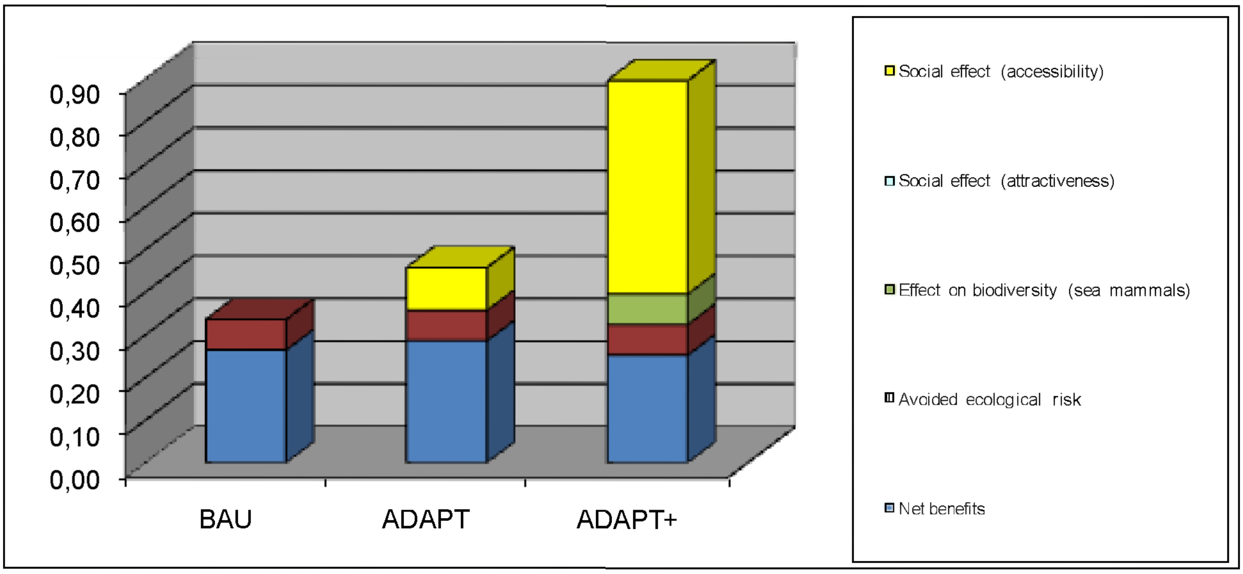


Figure 15: Scores and ranking of the strategies for run E CLIMAR 2040 (M+/Mean)

It is clear that the choice of the importance of an indicator will greatly influence the “benefit” or “merit” of a strategy. It is even quite possible that the choice of the weights will influence the final decision on the best strategy. For this analysis however, the strategy Adapt+ always comes out as the best strategy, regardless the choice of the weights. The reason behind this is the fact that Adapt+ scores good for two out of the indicators while the other strategies do not influence these indicators. If you would however opt for a purely economic decision (indicator “net benefits” with weight 1), the strategy Adapt+ would only rank 3rd place and the scenario Adapt would rank first.

2.4.5.6 Uncertainty analysis

The ex-ante assessment of climate change adaptation scenarios is not without problems. The outcome of the scenario assessment is only a forecast. The results need to be formulated in a conditional way, “given that input parameters (the values of the decision matrix as well as the weights attributed to the evaluation criteria) used in scenario x are …”. The input parameters are all somewhat uncertain. There are different types of uncertainty in the ex-ante appraisal of scenarios to limit the impacts of climate change: uncertainties in the knowledge of economic, social, ecological and physical systems, shortcomings in the way the economic, social, ecological and physical systems are modelled and, finally, data limitations. Tracking uncertainty is important for facilitating sound decision making. The influence of the uncertainties on the outcome of the scenario assessment can be evaluated on the basis of a Monte Carlo based uncertainty analysis. An example is presented in Figure 16 which shows the chance a certain scenario has to rank first, second, etc. when due consideration is given to uncertainty.

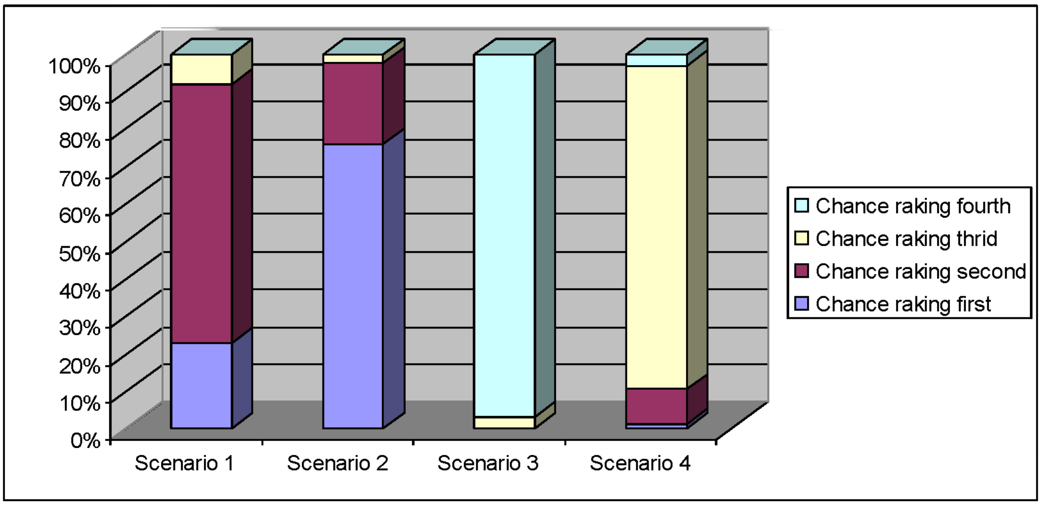


Figure 16: Expected ranking of the scenarios (fictive example)

Given the lack of information on uncertainty ranges in this first evaluation attempt of the adaptation strategy of the coastal tourism sector, the uncertainty analysis could not be carried out. Throughout this document however, we have reported on the probably high level of uncertainty of the assessment. We strongly encourage further research to incorporate quantitative uncertainty tools to accompany the multi-criteria analysis.

2.4.6 Evaluation tool of the case studies

2.4.6.1 Introduction

The evaluation tool for the sector tourism is already discussed during the general discussion of the evaluation tool in the previous section. For the case studies coastal defence and fisheries, some information is given in the next sections. More on the evaluation tool for the three case studies can be found in the technical reports.

2.4.6.2 Case study coastal defence

In this section, the adaptation strategies, as defined in 2.4.2.2, that are optimal from a welfare maximalisation point view are selected based on an extended CBA. The evaluation was done for a time horizon of 2040 only. The BAU approach then consists of dike heightening and beach nourishment, the ADAPT approach of the construction over very large beaches, the ADAPT+ approach of construction of very large beaches and of artificial islands and the REACT approach of construction of super dikes. The cost of the four adaptation strategies was evaluated in terms of building and maintenance costs, the benefits in terms of damage and victim risk reduction and gain of intertidal habitat (the indicators, developed in section 2.3.2.3.2). All monetary values were progressively discounted with a factor of 4% ()Table XXIII).

Table XXIII: Net benefits, beach area change and casualty reduction of the 4 adaptation scenarios, and standardized values (STD). BAU: BAU scenario; AD: ADAPT approach; AD+: ADAPT+ approach; REA: REACT approach.

Criteria	Unit	Adaptation scenario			
		2040 - BAU M+ Mean	2040 - AD M+ Mean	2040 - AD+ M+ Mean	2040 - REA M+ Mean
Net benefits	10^6 €	1.451	1.577	0.198	1.432
Reduced victims change)	-	191	191	191	191
Increase beach area	%	11.20	11.20	11.20	0.00
STD net benefits	-	0.91	1.00	0.00	0.89
STD reduced victims	-	1.00	1.00	1.00	1.00
STD increase beach area	-	0.11	0.11	0.11	0.00

Next, weights were attributed to the different indicators in order to arrive at a ranking of the adaptation strategies. Following the philosophy of the Master Plan Coastal Safety of the Flemish Government, victims are to be avoided at all cost, and this criterion was made twice as important as damage and habitat gain, resulting in a weight of 0.5, 0.25 and 0.25 for victims, net benefits and habitat change, respectively. The weight matrix is then combined with the standardized benefits matrix to give a ranking of the adaptation strategies (Table XXIV).

Table XXIV: Score matrix for the 4 adaptation scenarios, with time horizon of 2040, with the ranking of the scenarios according to weights of 0.50, 0.25 and 0.25 for casualties, damage and beach area change, respectively.

	2040 - BAU - M+ / Mean	2040 - ADAPT - M+ / Mean	2040 - ADAPT+- M+ / Mean	2040 - REACT - M+ / Mean
Net benefits	0.23	0.25	0.00	0.22
Avoided ecological risk	0.03	0.03	0.03	0.00
Social effect - Number of casualties	0.50	0.50	0.50	0.50
Total score	0.76	0.78	0.53	0.72
Rank	2	1	4	3

The three scenarios without the construction of islands are qualified as cost-efficient and as more or less equally good, although scenario 4 (superdike) performs less in terms of ecological benefits. Results of the sensitivity analysis (Table XXV) yield no different order of preference.

The CBA is elaborated in more detail in Reyns et al. (2011).

The most effective way from a CBA point of view to maintain the coastal protection standards within the context of climate change is strengthening the existing coastal defence line. Heightening and/or widening the beaches, dunes and dikes are to be preferred over building a complete new coastal defence line on the continental shelf. However, locally, islands with a different purpose than coastal protection can contribute to coastal safety. Where and how is a topic for additional research.

In the current analysis, only tangible losses like damage and victims were used to quantify the benefits from adaptation. Within the framework of the European Flood Directive, intangible losses such as health, cultural heritage,... must be incorporated in future risk assessments. At present, no scientifically sound methodology exists for this kind of analysis, or for the combination of tangible losses and intangible losses.

Table XXV: Results of the CBA sensitivity analysis. The weights for the three indicators were changed, and a new ranking was calculated. None of the changes alters the final ranking.

	Weights	2040 - BAU - M+ / Mean	2040 - ADAPT - M+ / Mean	2040 - ADAPT+ - M+ / Mean	2040 - REACT - M+ / Mean
Net benefits	0.500	0.45	0.50	0.00	0.45
Beach area change	0.167	0.02	0.02	0.02	0.00
Number of casualties	0.333	0.33	0.33	0.33	0.33
Total score		0.81	0.85	0.35	0.78
Rank		**2**	**1**	**4**	**3**
Net benefits	0.167	0.15	0.17	0.00	0.15
Beach area change	0.500	0.06	0.06	0.06	0.00
Number of casualties	0.333	0.33	0.33	0.33	0.33
Total score		0.54	0.56	0.39	0.48
Rank		**2**	**1**	**4**	**3**
Net benefits	0.500	0.23	0.25	0.00	0.22
Beach area change	0.250	0.03	0.03	0.03	0.00
Number of casualties	0.250	0.50	0.50	0.50	0.50
Total score		0.76	0.78	0.53	0.72
Rank		**2**	**1**	**4**	**3**

2.4.6.3 Case study fisheries

For the fisheries case-study it proved to be very difficult to follow the methodology for the development of an evaluation tool for adaptation strategies, as outlined within the CLIMAR framework. The complexity and uncertainties encountered on each preceding step, e.g., drafting climate change scenarios, performing an impact analysis, quantifying the impacts for the different climate change scenarios and quantifying these impacts, developing socio-economic scenarios and identifying adaptation measures, made it difficult to develop a realistic evaluation tool. Many assumptions were made and reality was oversimplified. Therefore the current tool should be considered as basis of which several components can be further elaborated. However the insights gained into the functioning of the Belgian fleet and the elements important for a successful transition to a sustainable sea fisheries sector are very valuable for further research and the formulation of advice to sector and policy makers.

2.4.7 Legal and policy evaluation of adaptation measures

The adaptation measures proposed by the different case studies have all been subjected to a legal and policy evaluation based on the following criteria: 1) Is there legal or policy support for the proposed adaptation measure? 2) Are there related international and national conventions, agreements and legislation? and 3) What is the institutional complexity of implementation? The information found was integrated in the AMFS and formed one of the criteria of the pre-assessment analysis (pre-MCA) resulting in the final list of adaptation measures combined in the CLIMAR adaptation strategies. A summary per case study of the most important findings is given in the next paragraphs.

2.4.7.1 Coastal defence

The Belgian coastal zone is a multifunctional area allowing a wide range of activities (tourism, dredging activities, sand and gravel extraction, shipping and fishing activities, ...). Consequently coastal defence measures need to be assessed on the basis of various (sectoral) laws, and involve a large number of governmental departments and agencies (public works and mobility, spatial planning, environment policy, nature conservation policy, water policy, tourism and recreation policy). Proposed coastal defence measures can be situated inland or seawards. This can lead to authority conflicts since competences in the coastal zone are divided between the federal and the regional governments. Furthermore, there are numerous regulations that need to be taken into account.

In accordance with article 6, §1, X, 4° of the Special Law of 8 August 1980 (*B.S.* 15 August 1980) the Flemish Region is competent for coastal defence. This competence is exercised by the independent agency without powers of jurisdiction - Agency for Maritime and Coastal Services (MDK). MDK is responsible for the protection of the coast against the sea, storm surges and flooding, as well as for the management of beaches and dunes relevant for coastal protection and coastal defence structures.

In order to be able to fulfil these competence the Flemish government can carry out activities in the territorial sea, on the continental shelf and in the exclusive economic zone, which are necessary for the performance of their regional competence, including coastal defence. Nevertheless, in principle the federal government has overall jurisdiction over the relevant parts of the North Sea (territorial sea, contiguous zone, continental shelf, exclusive economic zone).

This division of competences imply that both the federal government and Flemish government retain important prerogatives when it comes to implementing coastal defence adaptation measures. According to the Law on the protection of the marine environment in the marine areas under Belgian jurisdiction of 20 January 1999 (*B.S.* 12 March 1999) the federal government is empowered to provide permits for civil engineering works, such as the creation of artificial/multifunctional islands and floating dikes. However the same Law provides an exemption for coastal defence activities but not for recreational structures. Artificial islands can only be exempted from a federal permission if the artificial islands are strictly for coastal defence use, and will than require a building permit based on the Flemish legislation. Also in the context of an environmental impact assessment, a number of conflicts on authority can arise. When the coastal defence measures are situated seawards behind the baseline, in case of artificial islands and floating breakwaters, not only a Flemish Environmental Impact Assessment (EIA) will be required, but also a federal EIA with its own regulatory framework and various authorities involved.

Since the Belgian coastal zone and the BPNS are intensively used (*e.g.*, housing, commercial activities, nature conservation, dredging, sand and gravel extraction, ...) it is necessary to make sure that coastal defence measures such as super dikes, artificial islands and floating breakwaters are compatible with these activities and the spatial planning regulations thereon. In 2003 the Federal Minister for the management of the BPNS started with the implementation of a Master Plan introducing zones for certain activities, called a marine spatial plan. This process was divided into two phases in which a long-term strategy for the efficient use of the marine space is central. In 2003 new rules were established for sand and gravel extraction and the production of offshore electricity, by delineating zones in which these activities are permitted and incorporating a sustainable approach in the approval procedure. In 2005 the Special Protection Areas (SPAs) and Special Areas of Conservation (SACs) intended for the conservation of certain marine habitats or special species, and implementing the Bird-Directive and Habitat-Directive were delineated and the necessary management measures defined. For the moment future initiatives concerning marine spatial planning in the BPNS are being studied (Douvere et al., 2007). Concerning spatial planning on land, spatial allocation can be found in the Regional Spatial Structure Plans, Provincial Spatial Structure Plans and Municipal Spatial Structure Plans. Planning regulations are included in Spatial Implementations Plans, Municipal Zoning Plans and Urban Planning Regulations. Planning regulations can contain a building ban. In addition, a building permit is required under the Flemish legislation constructions, such as a super dike.

Although for beach accumulation (*e.g.*, applied in the context of beach nourishment) there is in principle no longer a building permit required (Decision of the Flemish Government of 1 September 2006, *B.S.* 10 October 2006).

Furthermore, also nature conservation legislation needs to be taken into account while implementing coastal defence measures. The division of competences ensures that, no single regulation for nature conservation exists. Depending on the area and designation of the area several regulations both federal as regional will be applicable. For instance the 'Baai van Heist' is designated as a specific marine reserve under the federal legislation as well as a SPA, SAC, protected dune area and beach reserve under the Flemish legislation. Consequently, for coastal defence works an appropriate assessment is required under de federal legislation as well as under the Flemish legislation. An appropriate assessment implies that any plan or project that is not directly connected with or necessary to the management of the site but likely to have a significant effect thereon, needs to undergo an appropriate assessment and can only be approved after having assured that the plan or programme will not have any negative effect on the site. A plan or project may nevertheless be carried out, in spite of a negative assessment of the implications for the site, if certain conditions are met. No alternative solutions should be available; it should concern imperative reasons of overriding public importance, including reasons of a social or economic nature; and all compensatory measures necessary to ensure that the overall coherence of Natura 2000 is protected, should be taken. Natura 2000 is a coherent European ecological network of SPAs and SACs. Compensatory measures can consist of: recreating a habitat on a new or enlarged site, improving a habit or in exceptional cases, proposing a new site under the Habitats-Directive (European Commission, 2002). This compensation needs to be active, meaning that compensation must be realised before the negative effects of a plan or project take place (European Commission, 2000). Coastal defence works can be defined as safety measures against flooding to protect housing and coastal infrastructure. These kind of adaptation measures can fall under the definition of overriding public interest and as such be allowed in an SPA or SAC after the necessary compensatory measures are adopted (Cliquet et al., 2009). Additionally, in Ramsar sites and protected dune areas, vegetation changes and changes in small landscape elements or its vegetation of wetlands are strictly prohibited. Exemptions can be allowed, by individual decision. Furthermore the Decree of 14 July 1993 concerning the protection measures for coastal dunes (*B.S.* 21 August 1993) also prohibits constructions in protected dune areas, except for activities benefiting nature conservation or coastal defence. Vegetation changes and changes in small landscape elements or its vegetation can be allowed in Natura 2000 sites and beach reserves, only after having received an environmental permit from the Flemish government.

Finally, depending on the coastal defence measures and the area in which they will take place it is possible that expropriation will need to take place. Private buildings or land necessary for the construction of coastal defence measures will need to be expropriated.

This falls under the competence of MDK after approval of the Flemish Minister competent for public works and mobility (Decision of the Flemish Government establishing the internally independent agency without powers of jurisdiction - Agency for Maritime and Coastal Services of 7 October 2005, *B.S.* 30 November 2005).

In the case of coastal defence measure for flooding, also the European regulations play an important role. In 2007, the European Flood Directive (Directive 2007/60/EC, 2007) compels Member States to develop Flood Risk Management Plans (FRMP). These FRMP should focus on prevention, protection and preparedness. The Flood Directive explicitly stated that "climate change can contribute to an increase in the likelihood and adverse impacts of flood events" (preamble §2) and that "FRMP should take into the likely impacts of climate change on the occurrence of floods" (preamble §14). Consequently, flood risk maps and management plans are already under development for the Belgian coastal zone taking into account climate change effects. Flemish Governement recently has established an Master Plan Coastal Safety'. This is prepared by a study using flood risk maps, taking into account sea level rise due to climate change (Couderé et al., 2009).

2.4.7.2 Fisheries

In assessing the institutional complexity of implementing adaptation measures for fisheries the question arises who is competent. Fisheries at sea are a Flemish competence, with the exception of issuing and controlling technical standards related to the vessels and manning. The latter is a federal competence. However, most competences are in the hands of the EU. Since 1983 the EU Common Fisheries Policy (CFP) governs fishing activities of the Member States, consequently most of the Belgian fisheries policy is based on the European Common Fisheries Policy. The latter implies that the EU establishes common targets, along with minimum conditions to be met, and criteria which must be respected to ensure a level playing field. Member States need to determine how these basic guidelines can best be translated into practice. Member States are responsible for the implementation and control of the EU fisheries policy and each Member State is free to choose the kind of national fishing industry it wants to encourage, in line with its fundamental economic choices, its social priorities and its cultural traditions (European Commission, 2009).

The current CFP dates from 2002 and aims at ensuring sustainable development of fishing activities from an environmental, economic and social point of view, meaning sustainable exploitation of living aquatic resources (Council Regulation No 2371/2002, 2002). Such a policy is necessary given the reality of overfishing, fleet overcapacity, heavy subsidies and low economic resilience. To solve these problems the current CPF introduced the precautionary approach to protect and conserve living aquatic resources, and to minimise the impact of fishing activities on marine ecosystems. To restore the fish stocks the principle of Maximum Sustainable Yield (MSY) has been established at the United Nations World Summit on Sustainable Development. MSY is an objective to manage all stocks at the highest theoretical yield that can be continuously taken from a stock under existing environmental conditions without significant affecting recruitment.

To reach this objective by 2015, the CFP sets quotas for each country, to limit catches of certain species by applying Total Allowable Catches (TAC) and multi-annual management plans, incorporating two features which are essential to any MSY-type approach. Firstly targets are set in terms of fishing mortality rates (*i.e.*, the rate at which fish is being removed from the stock). Secondly a long term perspective is introduced to respect the right of future generations to benefit from the bounty of the seas as much as we do. The CFP not only limits the quantity of what fishermen are allowed to catch, but it also provides a qualitative framework to protect fish stocks and the ecosystems by encouraging certain kinds of fishing practice, and discouraging, or banning, others and by regulating the number of days that can be fished during a year. These qualitative rules are collectively known as technical measures, *e.g.*, minimum mesh sizes for nets, closed areas and seasons, minimum landing sizes, limits on by-catch as a percentage of total catch, and incentives to adopt specific kinds of fishing gear which have been shown to reduce by-catch of unwanted organisms (European Commission, 2009).

In conclusion the CFP plays a dominant role in the implementation and regulation of adaptation measures for fisheries. For instance if the Belgian fishing fleet wants to opt for other fishing species/techniques this will have to comply with the TACs and technical measures set by the European CFP. In addition, the reform process of the CFP launched in 2009 must be taken into account. The 2002 CFP did not succeeded in its goal to reach a sustainable fisheries policy due to the incidence of problems such as unwanted by-catches and the principle of relative stability (*i.e.*, each Member States' share of each Community quota should remain constant over time). The latter leads to a discrepancy between the quotas allocated to Member States and the actual needs and uses of their fleets. The future CFP will move towards a more flexible system for national quotas, aligning with real needs of national fleets (COM 136 final, 2009). Although the White Paper on Adaptation stresses the need to take into account climate change in the future reformed CFP with a view to ensuring long-term sustainability, it is still not clear how this will be achieved in practice (COM 147 final, 2009).

Consequently it is very likely that adaptation measures such as changes in target species and fishing methods will take place if these changes are accompanied by sustainability measures. At international level, the International Union for Conservation of Nature (IUCN) recommended to ban destructive fishing techniques (Herr and Galland, 2009). At European level, the European Commission promotes to reduce the impacts of fisheries on non-target species and on marine and coastal ecosystems in its Biodiversity Action Plan for Fisheries (COM 162 final, 2001). Also the CFP should encourage improvement in the selectivity of fisheries operations (COM 369 final, 1999). At National level, the Belgian Strategic National Plan for Fisheries (2007-2013) ensures that future fleet needs to be energy and environmentally friendly. Especially for all trawl fisheries it is important to achieve improved species and length selectivity of the existing gear, and switch to more energy-efficient fishing techniques. Consequently the Belgian policy is also in favour to change fishing methods in a sustainable manner.

2.4.7.3 Tourism

Adaptation measures for tourism can be divided into two categories; those that are supported both at national and international level and those that are supported at international level but opposed at national level.

Measures in favour at all levels are the development of an innovative insurance, including "natural risk" effects, climate proof building standards, emergency planning and beach nourishment. The latter is also important for coastal defence. Also the United Nations Framework Convention on Climate Change (UNFCCC) and the European Union (EU) propose the use of insurance premiums anticipating climate change (COM 147 final, 2009). Optimising the use of insurance can provide incentives for private adaptation measures, if this is well thought trough by the insurance companies and the national and European public authorises (Dixit and McGray, 2009). An insurance scheme that reflects the level of risk exposure (such as risk-based insurance premiums) gives policyholders an incentive to invest in risk prevention and other adaptation measures (CEA, 2009). Already in the past, insurers have had resounding success in supporting the deployment of building code requirements and new technologies (Zurich Financial Services Group, 2009).

Managed retreat on the other hand is highly recommended at international and European level, since managed retreat is a good example of ecosystem-based adaptation. However this measures is seen as not very feasible at the Belgian coast due to dispersed habitation (Belpaeme et al., 2008). Nevertheless the Strategic Policy Plan for Coastal Tourism 2009-2014 stated that managed retreat will create new nature reserves, given that it will lead to the creation of wetlands. Therefore managed retreat can contribute to the quality of recreational tourism leading to a wider range of nature observations, although only under the conditions that managed retreat will be performed in a controlled manner and the nature reserves will be accessible for the public entirely or partly (Westtoer et al., 2009b). Ecosystem-based adaptation implies sustainable management, conservation and restoration of ecosystems in order to ensure the continued provision of vital services that help people adapt to adverse effects of climate change. Ecosystem-based adaptation integrates the use of biodiversity and ecosystem services into an overall adaptation strategy that is cost-effective, generate social, economic and cultural co-benefits and contributes to the conservation of biodiversity (Secretariat of the Convention Biological Diversity, 2009). The need for ecosystem-based adaptation is highlighted at several Conferences of the Parties (COPs) of the UNFCCC and the Convention on Biological Diversity (CBD), supported by the EU in the EU biodiversity Action Plan (COM 548 final, 2010), the Marine Strategy Framework Directive (Directive 2008/56, 2008) and the Integrated Maritime Policy (IMP) (COM 275 final, 2006).

From a perspective of legal feasibility and institutional complexity, there is a legal framework for most adaptation measures. However some legal amendments will have to take place to provide an adequate tool to support the adaptation measure. For instance, since 2006, insurance systems already cover the risk of flooding and other natural hazards in the mandatory home/fire insurance (Wet op de Landverzekerings-overeenkomst, *B.S.* 20 Augustus 1994). Insurance companies have the right to make a premium distinction according to the place where the insured household or business is located (*e.g.*, in a risk area or not). Households or businesses in a risk area can only get an insurance coverage for natural hazards at a very high premium or have the option to conclude an insurance cover via the pricing agency of the government. This agency will fix the premium rate and set conditions. If the damage exceeds the compensation of the insurance company, the remainder will be paid by the state owned National Disaster Relief Fund. Furthermore, if the natural disaster is recognised by a Royal Decree an additional compensation will be paid by the National Disaster Relief Fund for those goods that are not insurable by the standard fire insurance. The system of a mixed compulsory insurance and state intervention has the advantage that risks are spread among various actors (households, businesses, private insurer and the government). The governmental responsibility in case of flood damage ensures that the government will fulfil its coastal defence protection duties, such as dike maintenance. Differences in premiums also act as an incentive for households and businesses to take their own measures to reduce risks. Nowadays the Law on insurance stipulates the general binding conditions which insurance companies definitely need to take into account, but still leaves much room for private insurers to fill in the modalities of the insurance contract. The law determines the maximum refund and franchise as well as some goods that can be excluded, unless expressly stated in the insurance contract. This leads to different rates of premiums, franchises, goods that are excluded or included depending on the insurance company. For example some insurance companies are working with a uniform premium, while others apply a rate scale where the amount of the premium depends on the area you are living in. Yet there are still no climate proof building standards imposed and as insurance companies can chose the way of premium payment, there is no clear differentiation in climate change premium rates depending on the area of residence. To overcome this problem amendments need to be made to the existing law (*i.e.*, Wet op de Landverzekeringsovereenkomst, *B.S.* 20 Augustus 1994).

For the prohibition of activities, the general rule is that the authority that is competent for the activity has prohibiting powers. This can be done by an amendment of the Royal Decree of 4 August 1981 concerning a Police and Shipping Regulation for the Belgian territorial sea, the ports and beaches of the Belgian coast (*B.S.* 1 September 1981) or by police regulations adopted by municipalities. Furthermore, the Provincial Spatial Implementation Plan for Beaches and Dikes provides for allocation and authorisation requirements for constructions on beaches and dikes, for example bathing cabins, surf and sailing clubs, points of sale for drinks and temporary constructions for specific events. Temporary constructions not event specific can be permitted by the College of Mayor and Alderman. In practice it happens that such constructions remain throughout the whole year. This raises the question of who is liable in case of potential damage due to flooding. Therefore it is recommended that infringements are followed up and rectified.

Emergency planning is another example of an adaptation measure for tourism which already has a legal framework (Royal Decree of 31 January 2003 on the establishment of an emergency plan for crisis events and situations that require the coordination or management at national level, *B.S.* 21 February 2003). Depending on the size of the event, the geographical area, the number of casualties, the likely effects on humans and the environment and the resources to be employed, one can distinguish 4 phases of emergency planning. In phase 1 and 2 the coordination takes place at local/municipal level; in phase 3 the coordination takes place by the Provincial Governor and in phase 4 the coordination takes place by the Minister of Home Affairs. The Royal Decree of 16 February 2006 concerning emergency and intervention plans (*B.S.* 15 March 2006) determines that every municipality or province need to drawn up two kinds of plans, a general emergency and intervention plan (EIP) and a specific EIP. Flood risks are localized risks so a specific EIP needs to be established, both at provincial and municipal level. The Province of West-Flanders has started the development of a general EIP for the coast, including the harbours. Assistance with emergency planning for yachts and other recreational crafts in marinas will be developed at the level of municipalities. The exact content of these EIPs is still unknown. At National level the Minister of Home Affairs, in coordination with the emergency centre, is also developing an emergency plan for national disasters and floods. Finally, a contingency plan for the North Sea was drawn up after the Herald of Free Enterprise catastrophe in 1989. This contingency plan existed by mutual tacit agreement between all concerned parties and was endorsed by Ministerial Decree of 19 April 2005 (*B.S* 25 May 2005). At the moment the Governor of West-Flanders in cooperation with other competent partners such as the coastguard are revising the contingency plan for the North Sea (Debyser, 2006). In conclusion, although there is already a legal framework in place to develop contingency plans, most plans are still under development. A contingency plan is not a rigid document. It is an evolving matter, which entails that the plan should constantly be adjusted to changing circumstances, such as the effects of climate change (*e.g.*, extreme storm events and flooding).

2.4.8 Integration and synergies

2.4.8.1 In general: the International, European and national adaptation policy

Adaptation to climate change is a process by which strategies to moderate, cope with and take advantage of the consequences of climate events are developed and implemented (IPCC, 2001). Adaptation calls for a new paradigm in the planning process, one that considers a range of possible future climate conditions and associated impacts. The CLIMAR adaptation strategies are not stand-alone plans, but need to be seen as implementing strategies that describe how adaptation measures are to be incorporated into existing sectoral strategies, national and regional adaptation plans; also referred to as climate change adaptation mainstreaming (Niang-Diop and Bosch, 2005). Climate change adaptation mainstreaming is the integration of climate concerns and adaptation responses into relevant policies, plans, programmes, and projects at the national, sub-national, and local scales (USAID, 2009). Adaptation mainstreaming and the need to find synergies between climate change and the existing policies is also highlighted at international level and by the EU's adaptation policy as one of the key elements in adaptation to climate change.

Within the CBD, guidance to exploit the opportunities between climate change action and biodiversity can be found in several COP decisions and working papers, such as the need to establish ecosystem based adaptation responses. Ecosystem-based adaptation applies biodiversity and ecosystem services in an overall adaptation strategy. It includes the sustainable management, conservation and restoration of ecosystems to provide services that help people adapt to the adverse effects of climate change and provide cost-effective ways to address climate change. Ecosystem-based adaptation includes for instance coastal defence through the maintenance and/or restoration of coastal wetlands to reduce coastal flooding and coastal erosion. Measures to increase the adaptive capacity of species and ecosystems in the face of accelerating climate change include for instance strengthening of protected area networks (Secretariat of the Convention Biological Diversity, 2009). Consequently an ecosystem-based approach provides a flexible framework to address climate change mitigation and adaptation in a broader perspective (Secretariat of the Convention on Biological Diversity, 2003). The pre-assessment analysis of the CLIMAR-project also took into account the ecosystem based approach. Preference was given to adaptation measures acting on both the ecological and socio-economical aspects in a balanced way.

Mainstreaming climate change in the key policy areas of the EU is also one of the four pillars of the European policy to come to a European adaptation strategy (COM 147 final, 2009). The approach pursued by the EU is an integrated approach to both water management and to the management of marine and coastal zones, including measures to mainstream adaptation into sectoral policies. Adaptation efforts need to be integrated into the implementation of existing EU water legislation and marine and coastal zone legislation and policies, such as the Water Framework Directive, the Flood Directive, the Marine Strategy Framework Directive, the ICZM Recommendation and Roadmap for Maritime Spatial Planning.

At national level climate change also needs to be integrated into the planning process. The question arises: "how to facilitate decision-making in the planning process in the light of climate change?". SEA is particularly relevant in this context. SEA is already a widely accepted and legally embedded tool. SEA involves assessing and evaluating the possible impacts, whether adverse or beneficial, that a strategic action (e.g., a plan or programme) may have on the environment. It must be noted that SEA identifies the impacts of a proposed plan or programme on the environment rather than the impact of environmental change, such as climate change on the plan or programme. This means that the inclusion of adaptation considerations, which anticipates the effects of climate change, is not strictly included into the aim of SEA. However, the plan-maker needs to take into account the effects climate change will have on the plan or programme, since this can lead to mal-adaptation practices and is not in line with the initial purpose of SEA, namely to enhance sustainable development.

Furthermore SEA is seen by the EU and the Organisation of Economic Cooperation and Development (OECD) as a useful tool to facilitate decision-making in the light of climate change adaptation. SEA can address problems and promote actions on adaptation to climate change into the planning process, and can evaluate the environmental impacts of adaptation strategies as well as highlight possible conflicts with other existing regional/national plans and programmes. Though experience and empirical evidence on the inclusion of climate change adaptation considerations in programmes and plans through the SEA is not yet well known. Up till now the European Commission did not publish guidelines on how to deal with the inclusion of climate change adaptation into a SEA. However, the European Commission, in the follow-up of the White Paper on Adaptation, is working on guidelines on how to integrate climate change impacts into the SEA-Directive. In 2008 the OECD published an Advisory Note on SEA and adaptation to climate change (OECD/DAC, 2008). The afore-mentioned Advisory Note aims to demonstrate how SEA facilitates the integration of climate change adaptation considerations into planning and decision-making.

The Advisory Note states that not all SEAs should include climate change considerations, only those plans, policies and programmes that are likely to be influenced by, and hence need to adapt to climate change or influence adaptive capacities in some way to integrate climate change considerations into the SEA process. In order to do so a climate lens can be adopted. A climate adaptation lens is an analytical process/step/tool to examine a plan, policy or programme. The main part of the Advisory Note sets key questions which should be asked in the process of integrating climate change considerations into SEA, especially in the first phase or the scoping phase and the second phase or the implementation phase. This Advisory Note is very useful for states to adapt their existing legally embedded SEA process to adaptation to climate change (OECD/DAC, 2008). Several countries such as The Netherlands and Scotland already developed such guidelines on a voluntary basis. Although it is highly recommended that the European Union establishes clear guidelines on how to integrate climate change adaptation concerns in the SEA to encourage Member States to make their planning process more 'climate proof'.

Several entry points to include climate change adaptation considerations in the procedural requirements of SEA can be found. At the screening phase it can be assessed whether the scope of the plan or programme justifies considering climate change risk and vulnerability, by investigating if the plan or programme is climate change sensitive. In the scoping phase it can be determined what climate change variables and elements of the plan or programme need to be assessed, as well as which adaptation options can be included. The environmental report assesses the likely significant effects on the environment of the plan and programme. Climate change can influence these effects in the future and therefore climate change impacts on the plan or programme need to be assessed in the baseline description, as well as the influence of other relevant adopted plans and programme. Significant problems and constrains caused by climate change on the plan and programme should be identified.

At the implementation and monitoring phase climate change indicators can be taken into account to make sure that the plan and programme is climate proof. Finally the public participation process, which preferably takes place as early as possible to avoid public resistance at the end of the process by adopting the plan or programme, will lead to an increased climate change awareness.

Integration and synergies do not only mean that policies need to integrate the climate change concern but also that synergies need to be found between adaptation practices of neighbouring countries, within adaptation policies in countries and between sectors.

Impacts of climate change will vary by region, with coastal and flood plains particularly vulnerable. Adaptation measures will need to be carried out nationally and regionally. The role of the European Union will be to support these efforts through an integrated and coordinated approach, particularly in cross-border issues and policies which are highly integrated at EU level. For this reason the White Paper on Adaptation calls on member states to take action to cope with climate change and to cooperate and share information on adaptation strategies. The Flood Directive and Water Framework Directive for instance hamper the need for an coordinated approach, since this will ensure an overall effective approach and help avoid mal-adaptation measures (SEC 386/2; 2009) The absence of a coherent approach could lead to increasing conflicts between countries or regions in the context of climate change. For example, developing activities that minimise the retention capacities upstream, might lead to unnecessary floods downstream. These effects will have to be addressed at river basin scale (Delsalle, 2010).

The integration approach of the Belgian adaptation policies is mainly a "bottom-up" approach. Due to the division of competences both the federal government as the regions are competent to develop adaptation strategies and plans each in their own sphere of jurisdiction. In 2010, one Belgian adaptation strategy has being developed. This adaptation strategy reaffirms the need for a coordinated and integrated approach in which the context specific elements of each Region are respected and stakeholders are engaged. Related to the development of an adaptation plan a "bottom up" approach is put forward as one of the principles. Adaptation initiatives should be established at a local level, starting from sectoral adaptation plans combined in regional adaptation plans. These plans should include the different actions that have been taken or are planned to adapt to climate change. Adaptation measures should have co-benefits and/or be win-win (beneficial for both adaptation and mitigation) or be no-regret measures (beneficial irrespective of uncertainty in future climate change forecasts). Additionally measures related to vulnerable groups should be prioritised. Stakeholder participation is seen as a key element in the development of adaptation plans. Consequently, as a last step the regional adaptation plans will form the basis for the development of a national adaptation plan. This would be complementing the current national adaptation strategy and will identify synergies between the different regional adaptation plans.

Finally, in order to reach integration between different sectors, especially at the coastal zone, the ICZM recommendation of the EU and Belgium's national implementation process on ICZM is of importance. ICZM promotes the sustainable management of coastal zones and encourages decisions affecting coastal regions to be taken at the most appropriate level, through cooperation and integration planning, involving all the relevant players at the field. Good coastal zone management should explicitly acknowledge the uncertainty of future conditions, such as climate change and promote flexible and adaptable policies (European Commission, 2001). ICZM has been recognised as the most appropriate process to deal with current and long-term coastal problems. Climate change is one of those long-term coastal problems. ICZM is an iterative and evolutionary process, which not only deals with today's problems but also is flexible enough to adapt to as yet unforeseen issues that may arise in the future. ICZM includes adaptation to climate change and sea-level rise by developing and implementing a continuous management capability that can respond to changing conditions (Feenstra et al., 1998). The EU ICZM process resulted for the Belgian coast in the establishment of the Coordination Point for Integrated Coastal Zone Management in 2001. The main goal of the Coordination Point is to encourage and promote sustainable and integrated management of the coastal region in Belgium through structural consultation in the field of coastal management, objective communication to the wider public and monitoring of developments in the coastal zone. The Coordination Point is also a contact point for all parties dealing with cross-sectoral themes in the coastal zone. In addition with a view to improved coordination of the actions of the Belgian State at sea, a national Coast Guard was set up in 2003. Both the Coordination Point and the Coast Guard play a coordinating role between the Flemish government and the Federal government, respectively related to coastal zone management and activities at sea as well as between the different coastal sectors. Since adaptation asks for an integrated approach and the Coordination Point is the main contact point for all parties dealing with cross-sectoral themes in the coastal zone, the Coordination Point is seen as the appropriate body to promote an integrated climate change adaptation approach and discuss raising issues related to sectoral issues and the division of competences. However there must be noted that the Coordination Point is based on a declaration in principle rather than a cooperation agreement, which makes its institutional powers rather weak.

2.4.8.2 Integration/synergies in CLIMAR

Throughout the process of CLIMAR, integration has been one of our primary concerns. This relates both to a "top-down" integration (*e.g.*, relating the results of WP1 primary effects in an optimal way to the expected input of WP 2 secondary effects and measures) as well as a "horizontal" integration. The secondary effects as well as the measures have used the same typology and structure for the three different case-studies. If relevant, the measures are worked out together (*e.g.*, the use of sand nourishment is a measure relevant both for coastal flooding as well as for the case study of tourism).

The three different case-studies have used the same approach for setting up adaptation strategies and are being evaluated with the same evaluation tool (*i.e.*, a basic version of the tool in which the case study specific results are being implemented). Data and analysis of socio-economic scenarios are set up together or exchanged on a continuous basis. Via work meetings, the process of integration and synergies is continuously watched over. The various workshops held under the three different case-studies ensured that concerns of different stakeholders were taken into account during the process of drafting and assessing the adaptation measures. All stakeholders were invited to participate in the process.

2.5 CONCLUSIONS AND RECOMMENDATIONS

2.5.1 Primary impacts

A first step in the project was the identification of the primary impacts. A literature study clearly shows that large uncertainties still exist on the primary impacts. Furthermore, large regional differences can exist. On the effect of the climate change on the intensity and frequency of severe storms, *e.g.*, different contradictory conclusions can be found in literature. Based on the literature study, three different scenarios were presented, including an improbable 'worst case' scenario, which can be used to account for the uncertainty.

Statistical analysis was used to evaluate in detail the sea level rise at the Belgian coast (Oostende). Data from the Hydro Meteo System, together with data from the PSMSL were collected. Using the linear trend model, a sea level rise of 1.67 mm/year was calculated for the period 1927-2006. Other models (piece-wise linear, 2^{nd} and 3^{rd} order) were used as well, which suggest that the present SLR lies close to 4.4 mm yr^{-1}. The statistical analysis of the waves and the wind speeds showed decadal variability, related to the NAO. The long term trend and the linear regressions give some indication of a small decrease in significant wave height and wind speed over the Belgian coastal waters. For the maximum wave height and wind speed, the conclusions are less clear. Furthermore, a shift in wind direction to south westerly winds was observed. One can conclude that the available information is not sufficient to give conclusive statements on the possible change in storminess. Also in literature, some conflicting publications can be found. More research is necessary. Finally, the statistical analysis of sea surface temperature data indicated a clear increase: the highest increase was found in the central North Sea with an increase of about 0.05 °C yr^{-1}.

Moreover, different numerical models are being used to simulate the current situation and to assess the changes under the influence of the changes as described in the scenarios, *e.g.*, sea level rise and/or increased wind speed. It can be concluded that a sea level rise of 2 m and an increase in wind speed of 8 % by 2100 (WCS 2100), can have some important effects, *e.g.*, the maximum currents decrease with 10 % in the Westerschelde mouth and increase in the region between Nieuwpoort and Zeebrugge. Due to the sea level rise, wave breaking near the coast will diminish, resulting in higher waves near the coast, and higher coastal erosion. Also here more research is necessary, giving the importance for coastal defence.

2.5.2 Coastal defence

Concerning the coastal flooding case study, it has been shown that a wide range of direct and indirect secondary effects of climate change related to coastal flooding can be identified. Further it is clear that the flood risk calculations are an excellent tool to assess the impact of the most important secondary effects of climate change (damages and victims). The most important primary effects of climate change that increase flood risks are sea level rise and increased storminess (higher wind speed and wave conditions).

The flood risk model calculations carried out in the context of the CLIMAR project showed that, if we do nothing, the expected risk of damage and casualties within a few decades can increase by a factor of 10. The actual rate of change depends on the actual evolution of the North Sea storm climate, namely on phenomena such as the relative sea level rise, the evolution of the tide and the evolution of the frequency of severe storms with winds from the north and west. The rate of change would increase more if one takes into account the demographic trends and the associated demand for space, both however outside the scope of this study.

The most effective measure for the coast to maintain coastal safety consists of strengthening the existing coastal defence line. In practice this means to heighten and/or to widen the beaches, the dunes and the dikes. Investing in strengthening the existing coastal defence line can provide a solution avoiding an increase of the flood risks due to climate change, but additional research into non-structural measures could lead to an increase of their efficiency and thus contribute to, along with investments in strengthening the existing coastal defence line, in a most efficient mix of measures of coastal flood risk management. Additional efficient non-structural measures are for example the development of specific contingency plans for coastal flooding events, the strengthening of buildings so they remain structurally stable under the hydraulic impact of overtopping waves, introducing insurance schemes for damages by coastal flooding, or the adaptation of licensing procedures with respect to coastal safety.

This conclusion supports the current policy of the Flemish Government to 'grow with the sea' by nourishing beaches and other measures to strengthen the existing coastal defence line, as implemented in the Master Plan Coastal Safety 2050. The CLIMAR research results show the same approach to be promising when considering longer time horizons.

The investment cost to strengthen the existing coastal defence line in order to consolidate the flood risks is a factor 10 higher for a climate change scenario with a sea level rise of 2 m compared with a climate change scenario with a sea level rise of 0.3 m. This is due to the fact that in a climate change scenario with a sea level rise of 2 meters super storms can breach coastal defences along virtually the entire Belgian coastline, while in case of a small sea level rise of 0.3 m only a limited number of sites along the Belgian coastline are sensitive to breaching.

Results from this research further indicate that the creation of a new coastal defence line offshore by raising sand banks or building islands is not a valuable alternative compared to the strengthening of the existing coastal defence line. To guarantee coastal safety in future along the Flemish coast it is preferable to heighten and widen beaches, dikes and dunes, compared to the construction of a new coastal defence line in the sea (islands, breakwaters, ...). Perhaps there are local measures of raising sand banks or islands to be designed from different perspectives (e.g. harbour expansion or improved accessibility) that contribute significantly to enhancing coastal safety locally. Follow-up research on "intelligent islands" should aim to increase multi-functionality in which coastal safety is one of many perspectives to reach an integrated design.

The current flood risk methodology used in storm scenarios for the Flemish coast maps tangible losses (*i.e.*, casualties and economic damage), however European Floods Directive requires further research on intangible losses from flooding, such as health, environmental and cultural heritage-related effects. These aspects are in current practice of analysis of flood protection measures taken only in qualitative terms, in the absence of a scientifically validated methodology for intangible losses. It is a challenge for future researchers to both quantify the intangible impacts of coastal flooding and secondly to develop a methodology to combine these with the tangible impacts within an established framework of comparison such as a Multi Criteria Analysis and a Cost Benefit Analysis.

2.5.3 Fisheries

Sea fisheries are an important activity for the coastal community of Flanders from a socio-cultural-economic point of view. The strong specialization of the Belgian fleet with regard to fishing method (beam trawlers) and target species (mainly flatfish) makes the Belgian fisheries sector rather vulnerable to these continuously changing circumstances. Rising fuel prices, declining fish stocks, fluctuating fish prices, a global financial crisis and various European and national regulations threaten the viability of the sector. Recently the sector is faced with yet another factor which contributes to the growing uncertainty: climate change. Climate change will most probably impose additional pressure on the sea fishery, but may also offer opportunities.

The complexity of the Belgian sea fisheries sector and the ecosystem — of which the fish populations are a part — and the lack of knowledge about the interactions between the different ecosystem components hamper the assessment and quantification of the impacts of climate change relevant for the fisheries sector, especially on the long-term. The changing and uncertain environment the fleet is operating in and the uncertainty about the future of the fisheries sector, even without climate change, make it difficult to formulate a 'basic scenario' for the sector and to bring the time frame into conformity with the climate change scenario's (2040-2100). The fact that the sea fisheries fleet is not only active on the by the project partners studied Belgian Continental Shelf, but also operates in different ICES-areas and targets fish stocks which are managed on a European level, contributes to the complexity.

In addition the National and European fisheries policy steering the sector is complex and the uncertainty about the implementation of future policy, even on the short term, is considerable (*e.g.*, reform of the Common Fisheries Policy).

The effects of climate change important for sea fisheries are manifested mainly through changes in densities and distribution of various commercial fish stocks, the natural resources the sector depends on. For fish stocks currently fished by the Belgian sea fisheries fleet some general trends where observed. Scientists expect that these trends will continue: (1) a shift to the North or a migration to deeper waters, (2) increased densities in the Northern part of the habitat and decreased densities in the Southern part of the habitat, and (3) more southern species increase their northerly presence in response to climatic warming. Different studies show that more (fundamental) research focussing on the impact of climate change on the marine environment and (commercial) fish populations is essential for a better understanding and assessment of the expected effects. These insights can help to refine stock assessments and the formulation of quota (advice), which form the basis of fisheries management. This research can also underpin the ecosystem-based approach to fisheries which will be implemented in the near future.

Initially fishermen can follow the shifted fish populations, but legal provisions and practical feasibility (*e.g.*, distance to fishing ground; the accessibility and knowledge about the fishing grounds, the applicability of the fishing gear, etc.) limit this option to adapt. Reducing the existing fleet as adaptation measure is questioned by the industry as the fleet (nearly) reached its critical mass. A (seasonal) switch to other target species and other/adapted fishing methods can enable the fisheries sector to make optimal use of the changing fish populations/quota. Target (new) quota free species which become commercially interesting due to climate change is an option too.

Finally, it is noted that while mitigating or exploiting the effects of climate change was the starting point for identifying adaptation measures, several of these measures are general in nature and intended to support a sector which currently operates in difficult conditions. Climate adaptation measures for the Belgian sea fisheries sector can therefore largely fit in with the actions (which will be) taken to ensure a sustainable sector. After all, switching to adapted or other fishing techniques fits in with the transition to sustainable fisheries. The diversification of the fleet can help to enhance the viability and flexibility of the Belgian fisheries sector and improve the cost structure of individual companies. Via policy support (not just financially) and through guidance of both policy and sector by scientists this transition can be facilitated.

The collection and availability of socio-economic fisheries data linked to catch / landing data could be optimized, so that (the input to) the cost-benefit analysis can be refined. When assessing the vulnerability, adaptability, robustness and sustainability of the sector, these data will improve the basis for the social, economic and ecological aspects.

Also simplify and adapt the current regulations (European and national) to create a flexible but stable fishery management based on ecosystem approach, is an important step in the transition process. Ideally, the objective of this management is twofold.

On one hand it strives to conserve and/or repair commercial fish stocks and the ecosystem. On the other hand it gives individual ship owners the possibility, within a clear (legal) framework, to react quickly to changing circumstances and allows them to outline a healthy short- and midterm operational management. With its close connections to the environment and climate itself, tourism is considered to be a highly climate-sensitive economic sector. Despite the significant growth in research on tourism and climate change there are however considerable gaps in the previously published research regarding the knowledge of climate change adaptation and mitigation. With the selection of the sector tourism as third case study, a first attempt has been taken to tackle these problems for the Belgian coast tourism sector.

2.5.4 Coastal tourism

Tourism has evolved into one of the largest and fastest growing sectors in Europe. In addition, tourism, and especially coastal tourism, is highly dependent on environment and climate. Both have led to the definition of coastal tourism as a third case study within the CLIMAR project, which was initially not foreseen.

For the case study of tourism, the most important primary effects are temperature and air circulation patterns (precipitation, wind and currents) both determining the climatic conditions at the coast and sea level rise increasing the risks of natural hazards such as flooding and coastal erosion. Important secondary impacts besides the attractiveness of the coast in terms of pleasant climatic conditions and the loss of dune/beach area due to flooding or erosion, are the occurrence of sea mammals (geographical shift) as the food availability and temperature changes, increased damage costs to marinas due to sea level rise, changed accessibility of the coast due to damage infrastructure and an overall change in the turnover of the tourism sector, including the creation of new commercial activities (in water tourism, eco tourism). As can be seen climate change can influence the sector both in a negative and positive way.

In total 16 possible adaptation measures have been identified for the coastal tourism sector. Based on the MCA and stakeholder consultation we can conclude that on-line weather forecasting tools, preparedness of marinas, beach nourishment and road pricing have a high potential on success.

Despite the increase in research into tourism and climate change in Europe, the investigation quickly revealed that there are still many knowledge gaps about possible adaptation (in addition to mitigation) measures for tourism. A major problem in determining the relationship between climate and tourism is that both the direct and indirect effects vary greatly by location, and location-specific data for the Belgian coast are usually sporadic and only available in a non-centralized manner. In addition, by the complex interactions between tourism, climate, environment and community, it is hard to analyze the direct impact of climate. Moreover, the market is influenced by other factors like fuel prices, external markets, etc.

Although climate change often has a negative connotation, it probably entails for certain sectors, including coastal tourism, certain opportunities.

A negative effect of climate change on coastal tourism, which is closely linked to its physical surroundings, the beach and the sea, is the sea level rise and changing storm climate, which could lead to an additional loss of recreational beach. Secondly, the warmer climate (or wetter winters) provide better weather conditions for the coast. Note that this positive trend could increase the mobility problem during busy traffic periods. This precarious balance between these positive and negative impacts of a changing climate for coastal tourism will eventually translate into a particular economic outcome, which within CLIMAR is evaluated as positive for most scenarios.

During the execution of the project, CLIMAR showed the need to integrate socio-economic developments in the thinking process. Although this work was carried out for the 3 case studies, the methodology and first results were developed within the case study tourism. The lack of available information (data, methods, scenarios,...) urged us to put a lot more effort into this aspect than estimated at the start of the project. During the project a limited amount of information was made available which is then iteratively introduced in our methodology. The CLIMAR project recommends a broader study that specifically addresses the delivery of socio-economic scenarios in the context of long-term studies on the impact of climate change.

This study for coastal tourism (just as the coastal defense case) reveals that the methodology for assessing impacts of climate change through the use of indicators is necessary out of complexity, but also brings about the necessary constraints. Thus, besides the indicators defined in CLIMAR, there are numerous other possible effects that may qualify, such as the potential increase in the number of jellyfish in the sea, etc. The choice of indicators is strongly determining the further course of the process and therefore the selection of the most desirable adaptation strategy.

Besides tangible losses/ opportunities (such as loss of beach area) there are also the intangible losses/ opportunities (amenity of coastal climate and marine mammals, mobility problems, ...) to be quantified, and especially the translation of these intangible effects has proven not to be evident in practice. It is therefore a challenge for future researchers to better quantify these effects of coastal tourism and to develop further the methodology as well as combine these parameterized elements with the tangible aspects of a comparative research methodology as a Multi Criteria Analysis and Cost Benefit Analysis.

Furthermore, it appears that, although it is evident that coastal defense in Flanders takes the first place in the climate adaptation story, nobody should forbid us to maximize potential synergies with other sectors. The most effective measure for the coast to maintain security is to strengthen the existing seawall line. In practice this means that the dunes and beaches will be raising/ widening and/or dikes will be heightened/ expand, which directly contributes to the recreational value of the coast. However, there is an integrated vision needed from the start to develop joint opportunities and make joint priorities in the design of adaptation strategies. Despite the "willingness to cooperate" in CLIMAR, it became clear that more time and research is needed to continue this integration.

There is consensus on the role, both positive and negative, that the climate can play for coastal tourism. The importance of using this positive message on the effects of climate change, which is not the case for all sectors, cannot be underestimated. The answer to what measures are needed to cope with possible threats or opportunities appears to be much more difficult. A number of structural measures such as specific measures for damage mitigation and determination in the coastal marinas seem obvious, but currently lack a quantitative foundation. Other proposed adaptation measures have not yet concrete interpretation for coastal tourism and are either derived from similar applications in other sectors (e.g., bad weather compensation (Belgian Limburg), road pricing) or innovative ideas (e.g., insurance against climate risk, climate-proof building standards). CLIMAR realized a quantitative estimate for some of these measures. The other measures were described in a qualitative way. However, given the innovative nature of adaptation measures for coastal tourism, these estimates hold the necessary uncertainties and assumptions. A concrete interpretation/ refinement and estimation of associated costs for each measure is a study in itself and requires additional research and consultation with the sector.

During the execution of this (and the other) case studies the interaction with the "field" per sector (both policy makers and private organizations) has proven to be very useful. We especially want to thank Westtoer for their important contribution. It is also pointed out that it is difficult to interact with the private representatives of the tourism sector, given the fact that this is a sector with a lot of small enterprises. In a scientific project, it is not feasible nor the intention to focus on this interaction and participatory decision making. CLIMAR recommends an adaptation process for the coastal tourism sector: even though it's aimed at the long term, it must start from the current situation in a participatory mode.

Despite the difficulties discussed, it can be stated that CLIMAR made an important starting point: CLIMAR started to draw for a less "open" coastal sector in a scientific way possible consequences of climate change and started the thinking process of possible consequences. By CLIMAR some gaps in the Belgian coastal tourism have been identified that could provide a basis for further evaluation and possible inclusion in the policy strategy.

To date, the coastal tourism strategy is a policy defined for a shorter time horizon (five years) with concrete actions, in general focused on sustainability. If one wants to anticipate to the climate story, this broader policy vision must be framed, possibly using a graduated system. This can be worked out on two scales: a long term scale that describes the vision, including the climate issue and a shorter term to take concrete actions which include actions not in the way of future opportunities (no-regret measures).

2.5.5 Legal aspects

Although climate adaptation has been on the international agenda of the UNFCCC and CBD for a long time, this adaptation was mostly focused on adaptation measures in developing countries.

Only recently, attention is also given to the need for adaptation measures for developed countries as well as "mitigation". This is largely due to two factors: 1. The threat of impacts of climate change was earlier visible in developing countries 2. The call for support, both financially and in terms of capacity building, of developing countries to developed countries. However, nowadays it became also clear that an adaptation strategy and subsequent actions are necessary, even in developed countries, although there is no clear legal framework that is already into force. It is important that Belgium and Flanders, internationally, take a proactive attitude, given the potential threat to our coastal waters.

An adaptation strategy for the coastal zone and the subsequent actions, programs and projects cannot be separated from European obligations that are directly or indirectly applicable. This implies that an adaptation policy must take into account the EIA and their guidelines, Habitats and Birds Directives in the event of protected sites, but also the potential for integration between the Water Framework Directive, Marine Strategy Framework Directive and Flood Directive. The Directive on the right to environmental information, the public participation and access to justice in environmental matters is also relevant in this case, as is the Recommendation on integrated coastal zone management. It is, however, clear that the legal obligations of these guidelines strongly differ, if they are related to climate change adaptation measures. These EU obligations, except the recommendation integrated coastal zone management, are all implemented in the Flemish and Belgian law, but must be correctly applied. A minimum application is not enough.

Flanders, compared to other regions in Europe (cf. IMCORE project), has a clear vision for a climate adaptation strategy for coastal defence and the thereby corresponding measures. There is a coastal defence plan prepared that touches environmental effects through a EIA procedure. In line with the coastal defence plan, there will be, for each project, an EIA procedure applied. In the implementation, there will be a continuing need for transparency and leadership to fulfil the major functions. Also, there is a need of a legal clarification about taking decisions within the framework of the coastal defence and possibly other climate adaptation measures for the coastal zone. Good cooperation between different competent authorities is hereby crucial.

2.5.6 General

The complexity of the interactions between the primary effects, secondary effects for the human activities and the possible adaptation measures forced us to develop and follow a strict methodology: prioritisation of the physical effects and of the secondary effects, working with indicators to represent the secondary effects, prioritisation of adaptation measures... This implies that the interaction between the effects only can be taken into account in a restricted manner. Therefore, we recommend that more in-depth research is executed to assess for each sector (as well the sectors that were studied in the framework of the CLIMAR project as other relevant sectors) the effects of global climate changes in a quantitative way.

During the execution of the CLIMAR project, it became clear that also socio-economic evolution had to be accounted for. Due to lack of available information (data, methodology, scenarios) more time was used in that respect than initially estimated. During the execution of the tasks, a limited amount of information became available, that had to be incorporated iteratively in the methodology. Therefore we recommend setting up a larger research project to provide adapted socio-economic scenarios for climate change studies in a longer time frame.

During the execution of the case studies, the interaction with all actors was very useful. An adaptation process, also for longer time frames, has to start from the present situation in a participative modus. Unfortunately, it is not feasible in a scientific project, nor is it the intention to have an intense focus on this interaction and on the participative decision build-up. Therefore, it is recommended that, parallel to scientific research, the government develops for each sector "think-tanks" who can discuss freely over the adaptation process and the evolution of that sector on a longer time frame. The risk exists, that after the first "wave" of adaptation processes, the attention of the government fades away. Furthermore, the working method using the sectors proved to be very successful. Therefore, we recommend that the bottom-up approach in the different sectors is further stimulated, to allow 'intersectoral' discussions, once the definition of possible adaptation strategies for each of the sectors has been established.

Concerning the typology of the adaptation measures, the research showed that it is not simple to focus on other adaptation measures (besides technolicalmeasures) . This is partly due to the fact that more experience with these types of adaptation measures is available, and that the effect of these measures is easier to calculate, or at least this is assumed, partly due to the fact that the less technical measures (e.g., spatial planning, financial measures) more easily involve different sectors and more rapidly will cause 'tertiary' effects on other sectors. Therefore, it seems interesting to start upresearch for the most important non-technical adaptation measures from a certain typology and to assess the costs and the benefits of these measures from the point of view of different sectors.

The research in the CLIMAR project also focussed on the integration of the adaptation efforts, and the search for win-win situation between individual adaptation measures taken by different sectors. Different positive results were obtained when investigating adaptation measures that were considered in the different case studies. Beach nourishment, an adaptation measure considered for the coastal defence e.g., gave also positive feedbacks for the coastal tourism. On the other hand, inherent differences between the different sectors also here limit the integration of the adaptation measures. We recommend therefore to sufficiently account for the proper character of each sector (e.g., level of decision taking, geographical extent,) when trying to integrate the adaptation measures for the sectors active at the coast and at sea.

The coastal zone clearly is a "hot spot" for adaptation for climate change, as expected.

The coastal zone is subject to a wide spectrum of physical effects, as well from sea as from the land. It is a very intensive zone where different actors already have difficulties for sustainable multi-functional use. The current administrative and legal division of powers makes it even more difficult. Therefore further research on adaptation for the coastal zone will be necessary to face the challenge of climate change.

In the development of the activities in the projects, the strong fundamental interactions between "adaptation to climate change" and sustainability became immediately clear. From the methodological point of view, the definition of sustainability is however not developed enough. We had to conclude that Sustainability still is a concept that is interpreted by everyone from their own point of view. During the execution of the project, it was the goal of the project team to develop a methodology for the sustainability and to evaluate the costs and the benefits equally from economic, social and ecological point of view, in a way not to compromise the future generations. It is clear that this is not an easy task and it is therefore recommended to give enough attention to future research on sustainability.

The execution of the project was an exercise in multi-disciplinary research, with its ups and downs. All the time, we had to co-operate, and had to investigate time and energy to strive for this multi-disciplinary way of working. The gut feeling that this co-operation led to better results, can be proven, *e.g.*, by consistency between the structure, methodology and multisectoral adaptation measures. Multi-disciplinary research asks for more energy, but it is the only way for executing research in adaptation strategies. Therefore, the CLIMAR consortium pleads for a further and better administrative and financial framework to allow and even stimulate multi-disciplinary research.

3 POLICY SUPPORT

3.1 INTERNATIONAL LEVEL

The fifth Belgian national communication on climate change under the UNFCCC of 2009 refers to the primary and secondary impact assessment, undertaken by the CLIMAR project.

Renaat De Sutter acts as reviewer in the 5th Assessment Report (AR5) of The Intergovernmental Panel on Climate Change (IPCC), Working Group II.

3.2 EUROPEAN LEVEL

Renaat De Sutter has through its activities in EWA and IWA Specialist Group on climate change contact with and access to international and European institutions active on climate change. Both institutes are also involved in the development of the implementation of the Maritime Strategy Framework.

Through the ongoing INTERREG project Climate Proof Areas (CPA) in which Renaat De Sutter is partner, there is contact with marine and coastal scientists but also policy makers in the North Sea countries. In 2009 this project had workshops in Cambridge (United Kingdom) and Oldenburg (Germany), in 2010 in Ghent during which CLIMAR results could be exploited. This CPA will be clustered in 2011 with other Interreg-partners to provide a stronger voice towards European Policy makers.

The ongoing INTERREG IV B project “Innovative Management for Europe’s Changing Coastal Resource” (IMCORE), in which Frank Maes and Marian Willekens are partners, foresees regular contact with coastal scientists and local policy makers in North West European countries (Ireland, United Kingdom, France and the Netherlands). In 2008 this project had a workshop in Cardiff (United Kingdom), in 2009 in Ghent and Newcastle (United Kingdom), in 2010 in Schiphol (the Netherlands), Auray (France) and Aberdeen (United Kingdom) during which CLIMAR results were presented and used. This IMCORE project will from 2011 be part of a cluster with other INTERREG-projects to provide a stronger voice towards European Policy makers.

Renaat De Sutter has contacts with the partners of the European FP7 project MICORE. In a state-of-the-art report of this project, "Review of climate change impacts on storm occurrence" CLIMAR results were used.

During 2010 Annemie Volckaert attended the European working group on Economic and Social Assessment (WG ESA) with respect to the implementation of the Marine Strategy Framework Directive as Belgian representative for FPS Health, Food Chain Safety and Environment – Service Marine Environment.

As a partner of the OURCOAST project (Exchange of experience within ICZM) Annemie Volckaert has contact with the international network on ICZM. Within the OURCOAST project “Adaptation to climate change” has been pointed out as one of the main themes.

3.3 NATIONAL LEVEL

During the year 2010, the Flemish Government (the Department LNE as trigger, Mr. Johan Bogaert, Maarten van Leest) started with the drafting of the Flemish Adaptation Plan (by 2012). In 2010, a first study, "Building blocks to achieve a coherent and effective adaptation plan for Flanders" was carried out. This study was completed with a workshop on June 28, 2010 (see http://www.lne.be/themas/beleid/adaptatie). Our consortium made an important contribution to this study (especially by Prof. R. De Sutter as leader of the study). Beginning 2011, a National Adaptation Strategy (NAS) came out. The CLIMAR project is mentioned in the literature list. In 2011, the Flemish government, Walloon region and Brussels region will further collaborate to make a Belgian adaptation plan.

At 23 to 24 November 2010, the Belgian government organised a scientific conference on climate change "Adapt to the changing climate: the time to Intensify efforts" under the Belgian Presidency (see http://www.lne.be/en/2010-eu-presidency/events/climate-adaptation-conference/). The expertise of our consortium and research activities are valued in this initiative by the presence of Prof. R. De Sutter as a member of the steering committee of this congress. During the conference (only keynote speakers), there were two posters, where CLIMAR results were presented.

In 2009, the MIRA team of VMM, Flemish Government, prepared the Environmental Report Flanders 2009: Environmental Outlook 2030 (From Steertegem M, editorial). In the chapter "Climate change and water" Professor R. De Sutter was co-author. The CLIMAR project was one of the key-projects mentioned in the document. Jeroen Brouwers, VMM-Mira project leader, is also member of the follow-up committee of CLIMAR.

Frank Maes and Marian Willekens are involved as legal experts in the development of a coastal defence decree led by MDK (Tina Mertens) in which the CLIMAR expertise is used.

Els Vanderperren was asked to present the CLIMAR case study fisheries at the “5e Vergadering klimaatwerkgroep van het beleidsdomein LV – Klimaatadaptatie”, 21 March 2011, Brussels, organised by the Flemish Government - Department of Agriculture and Fisheries - Department of Monitoring and Study. As a result she was asked to write a text on climate adaptation for fisheries as part of the contribution this department will provide to the Flemish Government - Department LNE responsible for drafting the Flemish Adaptation Plan.

4 DISSEMINATION AND VALORISATION

4.1 PARTICIPATION IN INTERNATIONAL CONFERENCES AND WORKSHOPS

As the Belgian ambassador for the socio-economic aspects of ICZM, Annemie Volckaert has presented the CLIMAR project at the International ENCORA 1st Thematic Network Conference, Venice, 13 March 2007.

Toon Verwaest presented the CLIMAR project at Réunion d'information sur l'évolution des risques naturels littoraux liés au changement climatique: Les futures risques littoraux en Belgique, et comment les gérer?. 16 July 2008, Gravelines (Nord-Pas-de-Calais)

Renaat De Sutter presented "Development of a management tool for the equal evaluation of economic, social and ecological effects of adaptation scenarios for attenuating the effect of climate change induced" on the 11th International Specialised Conference on Watershed and river basin management, Budapest, Hungary, 4-5 September 2008.

Katrien Van der Biest presented the CLIMAR project at the International LITTORAL conference (Venice, 26 November 2008)

Els Vanderperren presented "Climate change: threat or opportunity for Belgian sea fisheries?" at the Congress 'Climate Change: Global Risks, Challenges and decisions', Copenhagen, Denmark, 10-12 March 2009.

Dries Van den Eynde presented the CLIMAR project at the SEAMOCS Conference, Effects of climate change: coastal systems, policy implications, and the role of statistics, Sliema, Malta, 18-30 March 2009.

José Ozer gave a presentation "On the variations in MSL and storminess along the Belgian coast (southern North Sea): some observational and model results" at the Workshop on Flood Vulnerability and Flood Protection in Tidal and Non-Tidal Regimes: North and Baltic Seas, 27–29 April, 2009, Delft, The Netherlands.

Katrien Van der Biest presented the CLIMAR project at the Tweetalige Conferentie Klimaatverandering : wat zijn de effecten op grensoverschrijdende gebieden?", Duinkerke, France, 13 May, 2009.

Annemie Volckaert presented "CLIMAR – Evaluation framework for adaptation against climate change (Belgian North Sea)". at the CIRCLE (Climate Impact Research Coordination for a larger Europe) workshop with as theme "Design and use of decision support systems". 15-16 July 2009, Bonn, Germany.

Ruchita Ingle presented "Effects of Climate Change on the Flemish water system (Belgium)." at the 1st IWA BeNeLux Regional Young Water Professionals Conference at Eindhoven, the Netherlands, 30th September to 2nd October 2009.

Renaat De Sutter presented "Climate change and socio-economic impacts on the long term sediment balance in the Belgian Part of the North Sea", on the Sednet Conference, Hamburg, Germany, October 2009.

Marian Willekens presented the CLIMAR project at the European IMCORE meetings in Newcastle, 22 October 2009 and in Schiphol, 2 February 2010.

MUMM hosted, from January 12 to 14, 2010, the ICES Workshop on "How Models help to understand Climate Change Impacts in Regional Oceans", a workshop where fifteen experts from countries bordering the North Atlantic gathered to discuss the modelling of climate impacts in regional oceans and how to anticipate the answer of ecosystems to these changes. The state-of-the-art in climate change modelling was presented, and a first start was made in the writing of a positioning paper on the use of numerical models for understanding the climate change. As coordinator of this workshop, Stéphanie Ponsar (MUMM) received the ICES Service Award.

Renaat De Sutter was invited keynote speaker on the International Conference "Deltas in time of climate change". 29 september – 1 oktober 2010. Rotterdam, Netherlands.

Renaat De Sutter, Dries Van den Eynde and Marian Willekens participated in the International conference organized by the Flemish government in the framework of the Belgian EU presidency, Brussels, 23-24 November 2010 and presented three posters.

Dries Van den Eynde will present the CLIMAR project on the BLAST Conference 2011, which will be organised in Oostende on 22 September 2011. The BLAST (Bringing Land and Sea Together) is a European Interreg IVB North Sea Region Programme.

4.2 PARTICIPATION IN NATIONAL CONFERENCES AND WORKSHOPS

As the Belgian ambassador for the socio-economic aspects of ICZM, Annemie Volckaert has presented the CLIMAR project at the National BENCORE conference (Brussels, 26 April 2007)

Renaat De Sutter, with contributions of Willems P. (CCI-HYDR project): Klimaatsverandering en het watersysteem: gevolgen in België. Presented at the B-IWA (Belgian International Water Association) Workshop, 4th June 2007, Brussels.

Katrien Van der Biest presented the CLIMAR project at the National Second BENCORE conference (Leuven, 30 May 2008)

Patrick Willems, with contributions of T. Verwaest, P. Baguis, A. Ducharme and P. Viennot presented "Impact van klimaatverandering op hydrologische en hydraulische extremen in de Schelde- en Seine-rivierbekkens en langs de Noordzeekust" at the Congres Water en Klimaatverandering, 14 en 15 October 2008, Antwerpen. Dries Van den Eynde, Renaat De Sutter, Katrien Van der Biest and Els Vanderperren participated in the Conference and presented a poster.

Marian Willekens participated the Symposium "Het Belgische EU-voorzitterschap: Het klimaat verandert?" organised by Argus and the 'Vlaams-Europees Vebindingsagentschap', Brussels, 26 October 2009

Renaat De Sutter and Dries Van den Eynde presented the CLIMAR project in the framework of a series of lectures on climate changes, organised by the Service International Cooperation of the city of Koksijde. Renaat De Sutter gave a presentation on "Climate changes and the impact for Flanders" on March 11th 2010, Dries Van den

Eynde gave a presentation on “Climate changes and the impact on the coast” on March 25th 2010.

Dries Van den Eynde and Renaat De Sutter participated in the Workshop ‘Climate adaptation and planning’, Brussels, June 28th 2010.

Vera Van Lancker presenteerde “Werken met de natuur: noodzaak of utopie?” op het Symposium “Het Kappa-plan: hoog tij(d) voor een veilige, natuurlijke en aantrekkelijke kust”, 1 oktober 2010, Bredene, Natuurpunt.

Dries Van den Eynde presented a poster at the VLIZ Young Scientist’s Day 2011, Brugge, Belgium, 25 February, 2011.

Vera Van Lancker presented ‘Sediment en morfodynamiek van de Belgische kustzone’ at the Workshop ‘Moet er nog zand zijn: een wetenschappelijke kijk op de kustlijn van morgen’, organised by the VLIZ, Bredene, May 24, 2011.

Dries Van den Eynde participated on the Workshop ‘Moet er nog zand zijn: een wetenschappelijke kijk op de kustlijn van morgen’, organised by the VLIZ, Bredene, May 24, 2011.

4.3 ORGANISATION OF CLIMAR WORKSHOPS

In the framework of the project, four workshops were organised by the CLIMAR consortium. A first more general workshop was organised, together with the INTERREG IV B project “Innovative Management for Europe’s Changing Coastal Resource” (IMCORE) on “The impacts of climate change in the marine environment and the coastal zone”, on April 21th 2009, at ILVO, Oostende.

Three other workshops were organised, for which the main goal was to involve the stakeholders, at the earliest stage possible, in the process of identifying the problem and the possible adaptive strategies for the different sectors. Therefore interactive workshops have been organized for the three considered coastal sectors within CLIMAR.

A first workshop "De Kust op maat van het klimaat" took place on Thursday 4 December 2008 at the InnovOcean site, Oostende (Belgium) and discussed the coastal defence. The second workshop "Crisis in de Visserij: Keert klimaat het tij?" took place on Tuesday 9 December 2008, ILVO-fisheries, Oostende (Belgium). This workshop dealt with the impact of climate changes on the fisheries sector, future developments in de fisheries sector and the possible adaptation strategies. The third workshop “Hoe dynamisch is ons kusttoerisme in tijden van klimaatverandering?” took place on Thursday 14 October 2010 at the Beach Palace Hotel, Blankenberge (Belgium).

More information on these workshops was given in section 2.4.3 - Public participation.

A Final Workshop was organised on May 25th in Bredene, where the results of the CLIMAR project were be presented. The workshop will be a part of a joint programme with VLIZ and Natuurpunt, who will organise on May 24th in Bredene a workshop on climate change and adaptation. The Final Workshop was attended by 71 participants. In the morning sessions, the partners of the CLIMAR project presented their work, and the main conclusions and recommendations were put forward. These were given to the participants as a separate report (Van den Eynde, et al., 2011a). In the afternoon a panel discussion was set up, which was moderated by Jan Seys (VLIZ). The participants of the panel discussion were: Yannick Ghelen (FOD Volksgezondheid, Veiligheid van de Voedselketen en Leefmilieu, dienst Klimaatsverandering), Johan Bogaert (Vlaamse Overheid, Departement Leefmilieu, Natuur en Energie), Stefaan Gysens (Vlaamse Overheid, Maritieme Dienstverlening en Kust), Johan Heyman (Vlaamse Overheid, Afdeling Landbouw- en Visserijbeleid), Steven Valcke (Toerisme Vlaanderen), Nico Pieterse (Planbureau voor de Leefomgeving, Nederland) and Renaat De Sutter and Frank Maes, representing the CLIMAR project team. Yannick Ghelen and Johan Bogaert started with a presentation of the Federal and the Flemish adaptation plan. Further, the discussion focused on the position of the different governments on the adaptation strategies, and on necessary future research. A report of the Final Workshop is given in Van den Eynde, et al. (2011b).

4.4 EDUCATION

Stijn Vandousselaere, 2007-2008. Climate Change in Belgian harbours: problem or opportunity. Master thesis, University Gent, Engineering Faculty. Promotor prof.dr.ir. Renaat De Sutter.

Renaat De Sutter made contribution to the presentation of Eric Schellekens, Arcadis, on the KVIV (Royal Flemish Engineering Society) conference, with topic “Climate Change and Flooding”, WLH Borgerhout, 19 February 2008.

Within the framework of CLIMAR Els Vanderperren, who’s responsible for the daily work on the case study fisheries, started with a PhD on the “Development and evaluation of long-term adaptation strategies for the Belgian sea fisheries sector”. Promoters are prof. dr .ir. Renaat De Sutter and George Allaert from the University of Gent, - Department of Civil Engineering (IR15) - Integrated water management and Environmental policy and partner in CLIMAR. Co-promoter is Dr. Ir. Hans Polet from ILVO-Fisheries and involved in CLIMAR as well. This PhD aims at developing/modelling fleet performance and structure, taking into account the current situation and including the associated parameters and drivers important for the fisheries sector. The first driver which will be detailed and implemented will be ‘climate change’. This model will consequently be used to evaluate the developed adaptation strategies and formulate recommendations. It is apparent that the work performed within the framework of this PhD will feed into the different work packages of the CLIMAR project and *vice versa*.

4.5 OTHER ACTIVITIES

The results of the research, the presentations of the Workshops and the publications, prepared in the framework of the project can be consulted at the CLIMAR website at http://services.arcadisbelgium.be/climar/

It is important to stress that the scientist of the CLIMAR group are having good contacts with scientists of other research programmes and projects. There is, e.g., good co-operation with the scientists of the Belspo Quest4D project.

5 PUBLICATIONS

5.1 BOOKS

Milieurapport Vlaanderen 2009: Milieuverkenning 2030 (Van Steertegem M, eindredactie). Klimaatverandering en waterhuishouding. Johan Brouwers, Bob Peeters, Patrick Willems, Pieter Deckers, Philippe De Maeyer, Renaat De Sutter, Wouter Vanneuville. D/2009/6871/038. ISBN 978-908040200-3. NUR 973/943. Also available in English.

5.2 PAPERS AND ARTICLES

Deckers, P., W. Kellens, J. Reyns, W. Vanneuville and P. De Maeyer, 2009. A GIS for flood risk management in Flanders. In: Geospatial techniques in urban hazard and disaster analysis. Showalter, P.S. and L. Yongmei (eds.), Geotechnologies and the environment, 2, 51-69 (Annex 1.1).

Kellens, W., T. Neutens, P. Deckers, J. Reyns and P. De Maeyer. Analyzing the effects of tourism dynamics on coastal flood risks. Submitted to Natural Hazards (Annex 1.2).

Ponsar, S., C. Schrum, J. Chassé, X. Fettweis, H. Gallee, N.P. Holliday , S.L. Hughes, C. Lett, M. Lindegren, D. Matei, E. Meyer, J. Ozer, P. Regnier, P.C. Reid, A. Sterl and D. Van den Eynde, 2011. Modelling ocean climate change evolution and impacts at (global to) regional scale. Chapter 12 in the Positioning Paper of ICES, in preparation.

Reyns, J., T. Verwaest en F. Mostaert, 2011. Een veilige kust, ook in de toekomst. De Grote Rede, 30, 15-18. (Annex 1.3).

Van den Eynde, D., 2011. Zeespiegelstijging: moeten we vrezen voor natte voeten? De Grote Rede, 30, 3-9. (Annex 1.4).

Van den Eynde, D., 2011. En wat met de stormen, worden die talrijker en/of krachtiger? De Grote Rede, 30, 10-14. (Annex 1.5).

Van den Eynde, D., R. De Sutter and P. Haerens, 2011. Climate change impact on marine storminess in the Belgian part of the North Sea. Submitted to Natural Hazards and Earth System Sciences. In review.

Vanderperren, E., R. De Sutter, and H. Polet, 2011. Climate change impacts affecting Belgian fisheries. To be published in Fisheries Research, in preparation.

Ullmann, A., A. Sterl, D. Van den Eynde and J. Monbaliu, 2011. Storm surges and atmospheric circulation: an analysis since 1950 for the Belgian coast and forecast for the 21th century. Submitted to Continental Shelf Research (Annex 1.6).

Willems P., W. Vanneuville, T. Verwaest, J. Berlamont, J. Monbaliu, 2008. Invloed van klimaatverandering in Vlaanderen. Het Ingenieursblad 77, 11-12, 28-33 (Annex 1.7).

5.3 CONFERENCE PROCEEDINGS

Brouwers, J., B. Peeters, P. Willems, P. Deckers, P. De Maeyer, R. De Sutter and W. Vanneuville, 2010. Environmental report Flanders 2030. Climate Change and water. Poster session. Climate Change and Water: time to intensify efforts.

International conference organized by Flemish government in the framework of the Belgian EU presidency. 23-24 November 2010 (Annex 1.8).

De Smet, L. and R. De Sutter, 2008. Development of a management tool for the equal evaluation of economic, social and ecological effects of adaptation scenarios for attenuating the effect of climate change induced. In: Proceedings of the 11th International Specialised Conference on Watershed and river basin managemen, Budapest, Hungary, 8 pp. (Annex 1.9).

De Sutter, R., V. Van Lancker, M. Fettweis, M., D. Van den Eynde and A. Volckaert, 2009. Climate change and socio-economic impacts on the long term sediment balance in the Belgian Part of the North Sea. Presentation at the Sednet Conference, Hamburg, Germany, October 2009 (Annex 1.10).

Deckers, P., J. Reyns, K. Holvoet, W. Vanneuville and Ph. De Maeyer, 2009. LATIS: the tool for flood risk calculations in Flanders. In: Book of abstracts: an overview of marine research in Belgium anno 2009. 10th VLIZ Young Scientists' Day. Special edition at the occasion of 10 years VLIZ. Mees, J. and J. Seys, (eds.), VLIZ Special Publication 43, 47 (Annex 1.11).

Ingle, R. and R. De Sutter, 2009. Effects of Climate Change on the Flemish water system (Belgium). Presentation at the 1st IWA BeNeLux Regional Young Water Professionals Conference at Eindhoven, the Netherlands, 30th September to 2nd October 2009, 8 pp. (Annex 1.12).

Van den Eynde, D., R. De Sutter, J. Ozer, S. Ponsar, K. Van der Biest, E. Vanderperren, T. Verwaest and A. Volckaert, 2008. Evaluation of climate change impacts and adaptation responses for marine activities: the CLIMAR project. Abstract for the International Symposium on the Effects of Climate Change on the World's Oceans, May 19-23 2008, Gijón, Spain, 1 pp (Annex 1.13).

Van den Eynde, D., R. De Sutter, H. Polet, T. Verwaest, F. Maes, A. Volckaert, E. Vanderperren, J. Ozer, S. Ponsar, K. Van der Biest and M. Willekens, 2008. CLIMAR – Evaluation of climate change impacts and adaptation responses for marine activities. Poster presented at the Conference 'Water and Climate Changes', University Antwerpen, October 14-15, 2008 (Annex 1.14).

Van den Eynde, D., J. Ozer and S. Ponsar, 2009. CLIMAR – Evaluation of the impacts of global climate changes and of adaptation strategies for marine activities at the Belgian Continental Shelf. SEAMOCS Conference on Effects of climate change: coastal systems, policy implications and the role of statistics. March 18-20, 2009, Sliema, Malta, Abstract (Annex 1.15).

Van den Eynde, D., J. Ozer and S. Ponsar, 2009. Climate Change Research at the RBINS, Data from Past and Present, Answers for the Future, Changes in Belgian Coastal Waters. Poster presented at the 'Opening of the Polar Station Princess Elisabeth, Antarctica, RBINS, February 15, 2009 (Annex 1.16).

Van den Eynde, D., R. De Sutter, H. Polet, T. Verwaest, F. Maes, A. Volckaert, E. Vanderperren, J. Ozer, S. Ponsar, K. Van der Biest and M. Willekens, 2009. CLIMAR – Evaluation of climate change impacts and adaptation responses for marine activities. Book of Abstracts, VLIZ Jongerendag 2009, Brugge, Belgium, 6 March, 2009, VLIZ Special Publication 41, 1 pp. + Poster (Annex 1.17).

Van den Eynde, D., R. De Sutter, H. Polet, T. Verwaest, F. Maes, A. Volckaert, E. Vanderperren, J. Ozer, S. Ponsar, K. Van der Biest and M. Willekens, 2010. CLIMAR. Poster session. Climate Change and Water : time to intensify efforts. International conference organized by Flemish government in the framework of the Belgian EU presidency. 23-24 November 2010.

Van den Eynde, D., J. Ozer and S. Ponsar, 2010. Assessment of the primary impacts of global climate change by literature study, statistical analysis and numerical modelling. Poster session. Climate Change and Water: time to intensify efforts. International conference organized by Flemish government in the framework of the Belgian EU presidency. 23-24 November 2010 (Annex 1.18).

Van den Eynde, D., J. Ozer and S. Ponsar, 2011. Assessment of the primary impacts of global climate change by literature study, statistical analysis and numerical modelling. Book of Abstracts, VLIZ Jongerendag 2011, Brugge, Belgium, 25 February, 2011, VLIZ Special Publication, 1 pp. + Poster (Annex 1.19).

Van der Biest, K., T. Verwaest, J. Reyns and W. Vanneuville. Assessing climate change impacts on flooding risks in the Belgian coastal zone. Abstract for the 9th International conference Littoral 2008, A Changing Coast: Challenge For The Environmental Policies, November 25-28 2008 Venice, Italy (Annex 1.20).

Van Lancker, V., S. Degraer, M. Fettweis, F. Francken en D. Van den Eynde, 2010. Werken met de natuur: noodzaak of utopie? In: Syllabus van het Symposium "Het Kappa-plan: hoog tij(d) voor een veilige, natuurlijke en aantrekkelijke kust", 1 oktober 2010, Bredene, Natuurpunt, 16-17 (Annex 1.21).

Vanderperren, E., R. De Sutter and H. Polet, 2009. Climate change: threat or opportunity for Belgian sea fisheries? In: Mees, J. and J. Seys (eds). VLIZ Young Scientists' Day. Brugge, Belgium: VLIZ, 74 (Annex 1.22).

Vanderperren, E., R. De Sutter and H. Polet, 2009b. Climate change: threat or opportunity for Belgian sea fisheries? Congress 'Climate Change: Global Risks, Challenges and decisions', session N° 35 'Adapting Coastal Zone and Marine Recourses to Climate Change'. Copenhagen, Denmark (Annex 1.23).

Vanderperren, E., R. De Sutter, H. Polet and G. Allaert, 2009. Development and evaluation of long-term adaptation strategies for the Belgian sea fisheries sector. 10th UGent-FirW PhD Symposium, 9 december 2009, Gent. (Annex 1.24)

Vanderperren, E., R. De Sutter, H. Polet and G. Allaert, 2009. Development and evaluation of long-term adaptation strategies for the Belgian sea fisheries sector. PhD winter school 2010, 1-4 February 2010 (Annex 1.25).

Verwaest, T., Ph. Vanpoucke, M. Willems and T. De Mulder, 2011. Waves Overtopping a Wide-Crested Dike. Proceedings Of The International Conference On Coastal Engineering, No. 32(2010), Shanghai, China (Annex 1.26).

Volckaert, A. and R. De Sutter, 2009. CLIMAR – Evaluation framework for adaptation against climate change (Belgian North Sea). CIRCLE (Climate Impact Research Coordination for a larger Europe) workshop with as theme "Design and use of decision support systems". 15-16 july 2009, Bonn, Germany, Abstract (Annex 1.27).

5.4 REPORTS

Belpaeme, K., H. Maelfait, A. Lescrauwaet, A. Cliquet, A., A. Vanhulle and K. Van der Biest, 2008. Verslag Workshop "De kust op maat van het klimaat". Oostende, CLIMAR, 7 pp.

Haelters, J., 2011. Climate change and marine mammals. Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01A, Management Unit of the North Sea Mathematical Models, Brussels, 8 pp. (Report 1).

Ozer, J., D. Van den Eynde and S. Ponsar, 2008. Trend analysis of the relative mean sea level at Oostende (Southern North Sea – Belgian coast). Technical Report CLIMAR/X/JO/200807/ EN/TR3, Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01A, Management Unit of the North Sea Mathematical Models, Brussels, 13 pp. (Report 2).

Ponsar, S., J. Ozer and D. Van den Eynde, 2007. Impacts of climate change on the physical and chemical parameters of the North Sea (literature study). Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01A, Management Unit of the North Sea Mathematical Models, Brussels, 70 pp. (Report 3).

Ponsar, S., J. Ozer and D. Van den Eynde, 2008. Impacts of climate change on the ecological parameters of the North Sea (literature study). Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01A, Management Unit of the North Sea Mathematical Models, Brussels, 37 pp. (Report 4).

Reyns, J., T. Verwaest en F. Mostaert, 2010. CLIMAR: Deelrapport 4 - Effect van het ophogen van de zandbanken voor de Belgische kust op de kustveiligheid, bij een superstorm. Versie 2_0. WL-Rapporten, 814_01. Waterbouwkundig Laboratorium, Antwerpen, België, 71 pp. (Report 5).

Reyns, J., T. Verwaest en F. Mostaert F., 2011. CLIMAR: Deelrapport 5 – Evaluatie van adaptiemaatregelen voor de bescherming van de Belgische Kust. Versie 1_0. WL-Rapporten, 814_01. Waterbouwkundig Laboratorium, Antwerpen, België.

Van den Eynde, D., 2011. Assessment of the primary impacts of global climate change using numerical models: hydrodynamic, wave and sediment transport modelling. Technical Report CLIMAR/X/JO/200807/ EN/TR5, Management Unit of the North Sea Mathematical Models, Brussels, 56 pp. (Report 6).

Van den Eynde, D., F. Francken, S. Ponsar en J. Ozer, 2008. Bepaling van de primaire impacten van klimaatsverandering: statistische analyse van metingen van golven, windsnelheid en –richting en van zeewatertemperatuur. Technisch Rapport CLIMAR/X/DVDE/200807/ NL/TR4, Rapport voorbereid in het kader van het CLIMAR project, uitgevoerd voor Federaal Wetenschapsbeleid, Contract SD/NS/01A, Beheerseenheid van het Mathematisch Model van de Noordzee, 40 pp. (Report 7).

Van den Eynde, D., R. De Sutter, F. Maes, E. Malfait, J. Reyns, E. Vanderperren, T. Verwaest en A. Volckaert, 2011. CLIMAR: Evaluatie van de impacts van klimaatsveranderingen en aanpassingsmaatregelen voor mariene activiteiten. Conclusies en aanbevelingen. Rapport voor Wetenschapsbeleid, Contract SD/NS/01, 12 pp. (Report 8).

Van den Eynde, D., R. De Sutter, F. Maes, E. Malfait, J. Reyns, E. Vanderperren, T. Verwaest en A. Volckaert, 2011. CLIMAR: Evaluatie van de impacts van klimaatsveranderingen en aanpassingsmaatregelen voor mariene activiteiten. Verslag Finale Workshop – Kustverdediging, visserij en toerisme: klimaatadaptatie warm aanbevolen? Rapport voor Wetenschapsbeleid, Contract SD/NS/01, 10 pp. (Report 9).

Van der Biest, K., 2008. Evaluation of climate change impacts and adaptation responses for marine activities (CLIMAR). Subdocument Coastal Flooding: General study and evaluation of potential impacts of climate change on the Belgian Part of the North Sea. Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01A, Flandern Hydraulics Research, Borgerhout, 71 pp. (Report 10)

Van der Biest K., T. Verwaest, J. Reyns en F. Mostaert, 2009a. CLIMAR: Deelrapport 2 – Kwantificatie van de secundaire gevolgen van de klimaatsverandering in de Belgische kustvlakte. Versie 2_0. WL Rapporten, 814_01. Waterbouwkundig Laboratorium, 77 pp. (Report 11).

Van der Biest K., T. Verwaest and F. Mostaert, 2009b. CLIMAR: Section Report 3 – Adaptation measures to climate change impacts along the Belgian coastline. Version 2_0. WL Rapporten, 814_01. Flanders Hydraulics Research: Antwerp, Belgium, 35 pp. (Report 12).

Vanderperren, E. and H. Polet 2009a. CLIMAR – Evaluation of climate change impacts and adaptation responses for marine activities. Subdocument: Belgian fisheries - sector analysis. ILVO Report N° CLIMAR_01. Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01A: ILVO - Institute for Agricultural and Fisheries Research, Animal Sciences - Fisheries: Ostend, Belgium, 44 pp. (Report 13).

Vanderperren, E., K. Van Craeynest, B. Verschueren and H. Polet, 2009b. CLIMAR – Evaluation of climate change impacts and adaptation responses for marine activities. Subdocument: Rapport of the CLIMAR Workshop '"Crisis in fisheries: does climate turn the tide? (09/12/08, Ostend)"(NL). ILVO Report N° CLIMAR_02. Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01A: ILVO - Institute for Agricultural and Fisheries Research, Animal Sciences - Fisheries: Ostend, Belgium, 56 pp. (Report14).

Vanderperren, E. and H. Polet, 2011a. CLIMAR – Evaluation of climate change impacts and adaptation responses for marine activities. Subdocument: Belgian sea fisheries - Climate change impacts affecting Belgian fisheries. ILVO Report N° CLIMAR_03. Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01B: ILVO - Institute for Agricultural and Fisheries Research, Animal Sciences - Fisheries: Ostend, Belgium, 56 pp. (Report 15).

Vanderperren, E. and H. Polet, 2011b. CLIMAR – Evaluation of climate change impacts and adaptation responses for marine activities. Subdocument: Belgian sea fisheries – Development and evaluation of adaptation strategies to climate change impacts affecting Belgian fisheries. ILVO Report N° CLIMAR_04. Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01B: ILVO - Institute for Agricultural and Fisheries Research, Animal Sciences - Fisheries: Ostend, Belgium, 56 pp. (Report 16).

Volckaert A. and R. De Sutter, 2009. Evaluation of climate change impacts and adaptation responses for marine activities (CLIMAR). Sector document - Coastal Tourism: Description coastal tourism along the Belgian coast. Arcadis Report N° CLIMAR_01. Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01A, Arcadis Belgium, Gent, 50 pp. (Report 17).

Volckaert A. and R. De Sutter, 2010. Evaluation of climate change impacts and adaptation responses for marine activities (CLIMAR). Sector document - Coastal Tourism: General study and evaluation of potential impacts of climate change on the Belgian Part of the North Sea. Arcadis Report N° CLIMAR_02. Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01A, Arcadis Belgium, Gent, 58 pp.+ Annexes (Report 18).

Volckaert A. and R. De Sutter, 2011a. Evaluation of climate change impacts and adaptation responses for marine activities (CLIMAR). Sector document - Coastal Tourism: Evaluation of adaptation strategies to climate change impacts along the Belgian coastline. Arcadis Report N° CLIMAR_03. Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01B, Arcadis Belgium, Gent, 58 pp. (Report 19).

Volckaert A. and R. De Sutter, 2011b. Evaluation of climate change impacts and adaptation responses for marine activities (CLIMAR). Guideline document. Arcadis Report N° CLIMAR_00. Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01A, Arcadis Belgium, Gent, 65 pp. (Report 20).

Willekens, M., F. Maes, L. Van Poucke, A. Cliquet and M. Berteloot, 2009. Report of the IMCORE/CLIMAR Workshop "The impacts of climate change in the marine environment and the coastal zone", Flanders Marine Institute, Ostend, 21 April 2009, 13 pp. (Report 21).

Willekens, M., F. Maes, L. Van Poucke, A. Volckaert, R. De Sutter and M. Berteloot, 2010. Report of the IMCORE/CLIMAR Workshop "How dynamic is Belgium's coastal tourism in times of climate change?", Blankenberge, 10 October 2010, 14 pp. (Report 22).

Willekens, M., F. Maes and E. Malfait, 2011a. CLIMAR – Evaluation of climate change impacts and adaptation responses for marine activities. Subdocument: Adaptation to Climate Change and Strategic Environmental Assessment. Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01A and 01B, Maritime Institute, Gent, 51 pp. (Report 23).

Willekens, M., F. Maes and E. Malfait, 2011b. CLIMAR – Evaluation of climate change impacts and adaptation responses for marine activities. Subdocument: Adaptation to Climate Change: the International and European Policy. Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01A and 01B, Maritime Institute, Gent, 53 pp. (Report 24).

Willekens, M., F. Maes and E. Malfait, 2011c. Evaluation of climate change impacts and adaptation responses for marine activities. Subdocument: Policy and legal evaluation of adaptation measures. Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01A and 01B, Maritime Institute, Gent, 72 pp. (Report 25).

6 REFERENCES

Beaugrand, G., 2004. The North Sea regime shift: Evidence, causes, mechanisms and consequences. Progress In Oceanography, 60 (2-4), 245-262.

Belpaeme, K., H. Maelfait, A. Lescrauwaet, A. Cliquet, A., A. Vanhulle and K. Van der Biest, 2008. Verslag Workshop "De kust op maat van het klimaat". Oostende, CLIMAR, 7 pp.

Bindoff, N.L., J. Willebrand, V. Artale, A. Cazenave, J. Gregory, S. Gulev, K. Hanawa, C. Le Quéré, S. Levitus, Y. Nojiri, C.K. Shum, L.D. Talley and A. Unnikrishnan, 2007. Observations: Oceanic Climate Change and Sea Level. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Groupe 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Brander, K., 2006. Is climate change moving the goalposts for fisheries management. Conférence Biodiversité: Science et Gouvernance Paris, 24-26 January 2005, 5 pp., available at: http://www.ifremer.fr/gascogne/actualite/colloque/atelier-biodiversite/D-at10-BRANDER.pdf.

Brander, K., 2007. Global fish production and climate change. Proceedings of the National Academy of Sciences USA, 2007, 104, 19709–19714.

Brooks, N., R. Nicholls, J. Hall, 2006. Sea Level Rise: coastal impacts and responses. Wissenschaftlichter Beirat des Bundesregierung Globale Umweltveränderungen (WBGU), 45 pp.

CEA, 2009. Tackling climate change: the vital contribution of insurers. Brussels, Belgium, 64 pp.

Church, J. A. and N. J. White, 2006. A 20th century acceleration in global sea level rise. Geophysical Research Letters, 33, L01602, doi:10.1029/2005GL024826.

Cliquet, A., C. Backes, J. Harris and P. Howsam, 2009. Adaptation to climate change Legal challenges for protected areas. Utrecht Law Review, Volume 5, No.1, 158-175.

COM 136 final, 2009. Green Paper: the Reform of the Common Fisheries Policy.

COM 147 final, 2009. White Paper: Adapting to climate change: Towards a European framework for action.

COM 162 final, 2001. Communication from the Commission to the Council and the European Parliament - Biodiversity Action Plan for Fisheries.

COM 275 final, 2006. Green Paper Towards a future Maritime Policy for the Union: A European vision for the oceans and seas "How inappropriate to call this planet Earth when it is quite clearly Ocean" attributed to Arthur C. Clarke.

COM 369 final, 1999. Communication from the Commission to the Council and the European Parliament - Fisheries management and nature conservation in the marine environment.

COM 548 final, 2010. Report from the Commission to the Council and the European Parliament - The 2010 Assessment of implementing the EU Biodiversity Action Plan.

Cook, R. M. and M. R. Heath, 2005. The impacts of warming climate for the management of North sea demersal fisheries. ICES Journal of Marine Science, Journal du Conseil 2005, 62(7), 1322-1326.

Couderé, K., K. Bleukens, I. Catteeuw, K. Trouw, 2009. Plan-MER voor het Geïntegreerd kustveiligheidsplan kennisgeving, Agentschap Maritieme dienstverlening en Kust – Afdeling Kust, 319 pp.

Council Regulation No 2371/2002 of December 2002 on the conservation and sustainable exploitation of fisheries resources under the Common Fisheries Policy, O.J. L 358, 31/12/2002 P. 0059 – 0080.

Debyser, J., 2006. The National Contingency Plan for the North Sea 'Rampenplan Noordzee': Present State and Critical Evaluation - Organization. Cabinet Governor of West Flanders, 5 pp.

Delsalle, J. 2010. Background document for Workshop 2: Infrastructural and spatial measures to manage water, presented at the Conference Adaptation to the changing climate time to intensify efforts, Brussels, 23-24 November 2010, 12 pp.

Demeyere, A., 2003. West-Vlaamse sector in de kijker - de visserij. West-Vlaanderen Werkt 2, 2003, 5-15.

deYoung, B., M. Barange, G. Beaugrand, R. Harris, R.I. Perry, M. Scheffer and F. Werner, 2008. Regime shifts in marine ecosystems: detection, prediction and management. Trends in Ecology and Evolution, 23, 7, 402-409.

Directive 2007/60/EC O.J. L 288, 06/11/2007, 2007. The European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks.

Directive 2008/56 O.J. L164/19, 2008. The European Parliament and the Council establishing a framework for community action in the field of marine environmental policy.

Dixit, A. and H. McGray, 2009. Countdown to Copenhagen: Options for the UNFCCC on Insurance in Copenhagen. World Research Institute, Washington, 2 pp.

Douvere, F., F. Maes, A. Vanhulle and J. Schrijvers, 2007. The role of marine spatial planning in sea use management: the Belgian case. Marine Policy, 31, 182-191.

Dulvy, N.K., S.I. Rogers, S. Jennings, V. Stelzenmüller, S.R. Dye and H.R. Skjoldal, 2008. Climate change and deepening of the North Sea fish assemblage: a biotic indicator of warming seas. Journal of Applied Ecology, 45 (4), 1029-1039.

Engelhard, G.H., J.K. Pinnegar and J.R. Ellis, 2008. Resolving climate impacts on fish stocks, Chapter 23 - Climate change and john dory.

European Commission, 2000. Managing Natura 2000 sites: The provisions of article 6 of the 'Habitats' Directive 92/43/EEC, Luxembourg, Office for Official Publications of the European Communities, 69 pp.

European Commission, 2001. EU focus on coastal zones, Luxembourg, Office for Official Publications of the European Communities, 29 pp.

European Commission, 2002. Assessment of plans and projects significantly affecting Nature 2000 sites, Luxembourg, Office for Official Publications of the European Communities, 76 pp.

European Commission, 2009. The Common Fisheries Policy a user's guide, Office for Official Publications of the European Communities, Luxembourg, 40 pp.

European Environment Agency, 2004. Impacts of Europe's changing climate: an indicator based assessment. Report nr. 2/2004.

Federaal Planbureau en Algemene Directie Statistiek en Economische Informatie, 2008. Bevolkingsvooruitzichten 2007-2060, Planning Paper 105.

Feenstra, J. F., I. Burton, J.B. Smith and R.S.J. Tol, 1998. UNEP Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies – Coastal zones. Vrije Universiteit Amsterdam, Amsterdam. 35 pp.

Fettweis, M. and D. Van den Eynde, 2003. The mud deposits and the high turbidity in the Belgian-Dutch coastal zone, southern bight of the North Sea. Continental Shelf Research, 23, 669-691.

Food and Agriculture Organisation, 2007. Adaptation to climate change in agriculture, forestry and fisheries: Perspective, framework and priorities (FAO's Interdepartmental working group on climate change). Rome.

Frid, C., C. Scott, O. Paramor, M. de Fatima Borgers, L. Hill, C. Vale, S.A. Ragnarsson, G. Oskarsson, J. Solmundsson, G. Piet, G.,De Metrio, M. Deflorio, S. Hansson, O. Hjerne, P. Dolmer, F.W. Köster, B.R. MacKenzie, C. Möllemann, H. Jensens, K. Gustavson, P. Munk, S. Jonasdottir and S. Munch-Petersen, 2008. Review Incorporating extrinsic drivers into fisheries mangement (FP6-022710-WP1). 430 p.

Giron, E., D. Sacre, W. Hecq, I. Coninx, K. Bachus, B. Dewals, S. Detrembleur, M. Pirotton, M. El Kahloun, P. Meire, L. De Smet and R. De Sutter, 2008. ADAPT - Towards an integrated decision tool for adaptation measures - Case study : floods. Final report phase I, Report for the Belgian Science Policy, Brussels, Belgium.

Herr, D. and G.R. Galland, 2009. The Ocean and Climate Change: tools and guidelines for action, International Union for Conservation of Nature, Switzerland, 27 pp.

Hertveldt B., B. Hoornaert en I. Mayeres, 2009. Langetermijnvooruitzichten voor transport in België: referentiescenario, Planning Paper 107, Federaal Planbureau en fod Mobiliteit en Vervoer.

Hillen M., S. Jonkman, W. Kanning, M. Kok, M. Geldenhuys and M. Stive, 2010. Coastal defense cost estimates. Delft University of Technology, in cooperation with Royal Haskoning, 85 pp.

Holgate, S. J. and P. L. Woodworth, 2004. Evidence for enhanced coastal sea level rise during the 1990s. Geophysical Research Letters, 31, L07305, doi:10.1029/2004GL019626.

Holthuijsen, L.H., N. Booij and T.H.C Herbers, 1989. A prediction model for stationary, short-crested waves in shallow water with ambient currents. Coastal Engineering, 13, 23-54.

ICES, 2002. Report of the ICES/GLOBEC workshop on the Dynamices of Growth in cod. ICES Cooperative Research Report N°252, 97 pp.

ICES, 2007. Report of the ICES/GLOBEC Working Group on Cod and Climate Change (WGCCC). By correspondence. ICES, 14 pp.

ICES, 2008a. The effect of climate change on the distribution and abundance of marine species in the OSPAR Maritime Area. ICES Cooperative research report N° 293, 43 pp.

ICES, 2008b. Report of the Workshop on Cod and future climate change (WKCFCC) 17-20 June 2008, ICES, Copenhagen, ICES CM2008 OCC:09. Copenhagen: ICES, 98 pp.

IPCC, 2001. Climate change 2001: Impacts, Vulnerabilities and Adaptation. Working Group II Contribution to the Intergovernmental Panel on Climate change Third Assessment Report Cambridge University Press, Cambridge, 1032 pp.

IPCC, 2007. Climate change 2007: Impacts, Vulnerabilities and Adaptation. Working Group II Contribution to the Intergovernmental Panel on Climate change Fourth Assessment Report. Cambridge University Press. Cambridge, 976 pp.

Klyashtorin, L.B., 2001. Climate change and long-term fluctuations of commercial catches: the possibility of forecasting. FAO Fisheries Technical Paper. No. 410. Rome, FAO., 86 pp.

Loewe, P. and G. Koslowski, 1994. The western Baltic sea ice season in terms of a mass-related severity index: 1879-1992. Part II: Spectral characteristics and associations with the NAO, QBO and solar cycle. Tellus, 50A, 219-241.

Luyten, P.J., J.E. Jones, R. Proctor, A. Tabor, P. Tett and K. Wild-Allen, 1999. COHERENS – A Coupled Hydrodynamical-Ecological Model for Regional and Shelf Seas: User Documentation, MUMM Report, Management Unit of the Mathematical Models of the North Sea, 914 pp.

Nationaal Instituut voor Statistiek, 2007. Bevolking per gemeente op 01/01/2007. http://www.statbel.fgov.be/ (31/01/08).

Niang-Diop, I. and H. Bosch, 2005. Formulating an adaptation strategy. In: E. Spanger-Siegfried, I. Burton, E. Malone and H. Saleemul (eds.), Adaptation Policy frameworks for Climate Change – developing strategies, policies and measures, UNDP, New York, 183-204.

OECD/DAC, 2008. Strategic Environmental Assessment and Adaptation to Climate Change. OECD Publications, 29 pp.

OSPAR Commission, 2000. Quality Status Report 2000, Region II Greater North Sea. OSPAR Commission, London, 136 + xiii pp.

Ozer, J., D. Van den Eynde and S. Ponsar, 2008. Trend analysis of the relative mean sea level at Oostende (Southern North Sea – Belgian coast). Technical Report CLIMAR/X/JO/200807/ EN/TR3, Management Unit of the North Sea Mathematical Models, Brussels, 13 pp.

Perry, A. L., P. J. Low, J.R. Ellis and J.D. Reynolds, 2005. Climate shift and distribution shifts in Marine fishes. Science, 308, 5730, 1912-1915.

Perry, R.I., P. Cury, K. Brander, S. Jennings, C. Möllmann and B. Planque, 2009. Sensitivity of marine systems to climate and fishing: Concepts, issues and management responses. Journal of Marine Systems.

Phillippart, C.J.M., R. Anadon, R. Danovaro, J.W. Dippner, D. Kenneth, S.J. Hawkins, G. O'Sullivan, T. Oguz and P.C. Reid, 2007. Impacts of climate change on the European Marine and Coastal Environment – Ecoystem approach, European Science Foundation, Marine Board, Paper 9, 82 pp.

Ponsar, S., J. Ozer and D. Van den Eynde, 2007. Impacts of climate change on the physical and chemical parameters of the North Sea (literature study). Management Unit of the North Sea Mathematical Models, Brussels, 70 pp.

Ponsar, S., J. Ozer and D. Van den Eynde, 2008. Impacts of climate change on the ecological parameters of the North Sea (literature study). Management Unit of the North Sea Mathematical Models, Brussels, 37 pp.

Reyns J., T. Verwaest en F. Mostaert, 2010. CLIMAR: Deelrapport 4 - Effect van het ophogen van de zandbanken voor de Belgische kust op de kustveiligheid, bij een superstorm. Versie 2_0. WL-Rapporten, 814_01. Waterbouwkundig Laboratorium, Antwerpen, België.

Reyns J., T. Verwaest en F. Mostaert, 2011. CLIMAR: Deelrapport 5 – Evaluatie van adaptiemaatregelen voor de bescherming van de Belgische Kust. Versie 1_0. WL-Rapporten, 814_01. Waterbouwkundig Laboratorium, Antwerpen, België.

Rijnsdorp, A. D., M.A. Peck, G.H. Engelhard, C. Möllmann and J.K. Pinnegar (eds.), 2010. Resolving climate impacts on fish stocks. ICES Cooperative Research Report No. 301, 371 pp.

Schubert, R., H.-J. Schellnhuber, N. Buchmann, A. Epiney, R. Griesshammer, M. Kulessa, D. Messner, S. Rahmstorf and J. Schmid, 2006. The future oceans – warming up, rising high, turning sour. German Advisory Council on Global Change (WBGU), 111 pp.

SEC 386/2, 2009. Commission Staff Working Document accompanying the White Paper Adapting to climate change: Towards a European framework for action, Climate change and Water, Coasts and Marine Issues.

Secretariat of the Convention Biological Diversity, 2003. Interlinkages between biological diversity and climate change: advice on the integration of biodiversity considerations into the implementation of the United Nations Framework Convention on Climate Change and its Kyoto Protocol – ad hoc Technical Expert Group on Biological Diversity and Climate Change, AHTEG on Biological Diversity and Climate Change, CBD Technical Series N° 10, 151 pp.

Secretariat of the Convention on Biological Diversity, 2009. Connecting Biodiversity and Climate Change Mitigation and Adaptation: Report of the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change. Montreal, Technical Series No. 41, 126 pp.

Siegismund, F. and C. Schrum, 2001. Decadal changes in the wind forcing over the North Sea. Climate Research, 18, 39-45.

Simpson, M.C., S. Gössling, D. Scott, C.M. Hall and E. Gladin, 2008. Climate Change Adaptation and Mitigation in the Tourism Sector: Frameworks, Tools and Practices. UNEP, University of Oxford, UNWTO, WMO: Paris, France.

Smits, A., S.M.G. Klein Tank and G.P. Können, 2005. Trends in storminess over the Netherlands, 1962-2002. International Journal of Climatology, 25 (10), 1331-1344.

Stiansen, J.E., A. Aglen, B. Bogstad, H. Loeng, S. Mehl, O. Nakken, G. Ottersen, G. and E. Svendsen, 2005. Including climate into the assessement of future fish recruitment, using multiple regression models. ICES CM 2005/O:25, 8 pp.

Sünderman, J., G. Becker, P. Damm, D. Van den Eynde, R. Laane, W. van Leussen, T. Pohlmann, W. van Raaphorst, G. Radach, H. Schultz and M. Visser, 1996. Decadal variability on the North-West European continental shelf. Deutsche Hydrografische Zeitschrift, 48, 3/4, 365-400.

Tasker, M.L.E., 2008. The effect of climate change onthe distribution and abundance of marine species in the OSPAR Maritime Area. ICES Cooperative Research Report N°293, 45 pp.

Tessens, E. and M. Velghe, (eds.), 2007. Uitkomsten van de Belgische zeevisserij 2006. [Results of Belgian marine fisheries 2006]. Dienst Zeevisserij: Oostende, Belgium. 31 pp.

Tessens, E. and M. Velghe, (eds.), 2008. De Belgische zeevisserij: aanvoer en besomming 2007. [Belgian marine fisheries: landings and totals 2007]. Dienst Zeevisserij: Oostende, Belgium. 104 pp.

Toerisme Vlaanderen – Dienst Planning and Onderzoek (2007). De Vlaanderen-Vakantieganger anno 2005. 178 p.

Toth, F., 2000. Decision analysis frameworks in TAR: a guidance paper for IPCC. In "Guidance papers on the cross cutting issues of the Third Assessment Report of the IPCC (Pachauri R. et al.). Intergovernmental Panel on Climate Change, Geneva, Switzerland, 53-68.

Tulp, I., R. van Hal and A. Rijnsdorp, 2006. Effects of climate change on North Sea fish and benthos. Wageningen: IMARES, 113.

USAID, 2009. Adapting to Climate Variability and Change. A Guidance Manual for Development planning. Washington, United States Agency for International Development, 148 pp.

Van Cauwenberghe, 1995. Relative sea level rise: further analyses and conclusions with respect to the high water, the mean sea and the low water levels along the Belgian coast. Rapport nr. 37 ter van de Hydrografische Dienst der Kust/

Van Cauwenberghe, 1999. Relative sea level rise: analyses and conclusions with respect to the high water, the mean sea and the low water levels along the Belgian coast. Rapport nr. 46 van de Hydrografische Dienst der Kust.

Van den Eynde, D., 1992. mu-WAVE: an operational wave forecasting system for the Belgian coast. In: Proc. 3rd Int. Workshop on Wave Hindcasting and Forecasting, May 19-22, 1992, Montréal, Canada, 313-324.

Van den Eynde, D., 2011. Assessment of the primary impacts of global climate change using numerical models: hydrodynamic, wave and sediment transport modelling. Technical Report CLIMAR/X/JO/200807/ EN/TR5, Management Unit of the North Sea Mathematical Models, Brussels, 56 pp.

Van den Eynde, D., F. Francken, S. Ponsar en J. Ozer, 2008. Bepaling van de primaire impacten van klimaatsverandering: statistische analyse van metingen van golven, windsnelheid en –richting en van zeewatertemperatuur. Technisch Rapport CLIMAR/X/DVDE/200807/ NL/TR4, Beheerseenheid van het Mathematisch Model van de Noordzee, 40 pp.

Van den Eynde, D., R. De Sutter, F. Maes, E. Malfait, J. Reyns, E. Vanderperren, T. Verwaest en A. Volckaert, 2011. CLIMAR: Evaluatie van de impacts van klimaatsveranderingen en aanpassingsmaatregelen voor mariene activiteiten. Conclusies en aanbevelingen. Rapport voor Wetenschapsbeleid, Contract SD/NS/01, 12 pp.

Van den Eynde, D., R. De Sutter, F. Maes, E. Malfait, J. Reyns, E. Vanderperren, T. Verwaest en A. Volckaert, 2011. CLIMAR: Evaluatie van de impacts van klimaatsveranderingen en aanpassingsmaatregelen voor mariene activiteiten. Verslag Finale Workshop – Kustverdediging, visserij en toerisme: klimaatadaptatie warm aanbevolen? Rapport voor Wetenschapsbeleid, Contract SD/NS/01, 10 pp.

Van der Biest K., T. Verwaest, J. Reyns, F. Mostaert, 2009a. CLIMAR: Deelrapport 2 – Kwantificatie van de secundaire gevolgen van de klimaatsverandering in de Belgische kustvlakte. Versie 2_0. WL Rapporten, 814_01. Waterbouwkundig Laboratorium.

Van der Biest K., T. Verwaest, F. Mostaert, 2009b. Section Report 3 – Adaptation measures to climate change impacts along the Belgian coastline. Version 2_0. WL Rapporten, 814_01. Flanders Hydraulics Research: Antwerp, Belgium.

van Keeken, O.A., M. van Hoppe, R.E. Grift, R.E. and A.D. Rijnsdorp, 2007. Changes in the spatial distribution of North Sea plaice (Pleuronectes platessa) and implications for fisheries management. Journal of Sea Research, 57 (2-3), 187-197.

Vanderperren, E. and H. Polet, 2009a. CLIMAR – Evaluation of climate change impacts and adaptation responses for marine activities. Subdocument: Belgian sea fisheries - sector analysis. ILVO Report N° CLIMAR_01. Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01A: ILVO - Institute for Agricultural and Fisheries Research, Animal Sciences - Fisheries: Ostend, Belgium, 44 pp.

Vanderperren, E., K. Van Craeynest, B. Verschueren and H. Polet, 2009b. CLIMAR – Evaluation of climate change impacts and adaptation responses for marine activities. Subdocument: Rapport of the CLIMAR Workshop '"Crisis in fisheries: does climate turn the tide? (09/12/08, Ostend)"(NL). ILVO Report N° CLIMAR_02. Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01A: ILVO - Institute for Agricultural and Fisheries Research, Animal Sciences - Fisheries: Ostend, Belgium, 57.

Vanderperren, E. and H. Polet, 2011a. CLIMAR – Evaluation of climate change impacts and adaptation responses for marine activities. Subdocument: Belgian sea fisheries - Climate change impacts affecting Belgian fisheries. ILVO Report N° CLIMAR_03. Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01B: ILVO - Institute for Agricultural and Fisheries Research, Animal Sciences - Fisheries: Ostend, Belgium, 56 pp.

Vanderperren, E. and H. Polet, 2011b. CLIMAR – Evaluation of climate change impacts and adaptation responses for marine activities. Subdocument: Belgian sea fisheries – Development and evaluation of adaptation strategies to climate change impacts affecting Belgian fisheries. ILVO Report N° CLIMAR_04. Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01B: ILVO - Institute for Agricultural and Fisheries Research, Animal Sciences - Fisheries: Ostend, Belgium, 56 pp.

Vanpoucke, Ph., P. Vanderkimpen, K. Van der Biest, J. Reyns, T. Verwaest, P. Peeters, K. Holvoet en F. Mostaert, 2008. Overstromingsrisico's aan de Vlaamse kust. Evaluatie van de zeewering. Deel 2: Resultaten. WL Rapporten, 718/2C, Waterbouwkundig Laboratorium and Universiteit Gent and Soresma-Haecon, Borgerhout, België.

Van Steertegem M. (eindred.), 2009. Milieuverkenning 2030. Milieurapport Vlaanderen, VMM, Aalst.

Verwaest, T., Ph. Vanpoucke, J. Reyns, K. Van der Biest, P. Vanderkimpen, P. Peeters, W. Kellens, W. Vanneuville, 2008a. SAFECoast: Comparison between different flood risk methodologies. Action 3B report - SAFECOAST Interreg IIIb North Sea Project.

Verwaest, T., Ph. Vanpoucke, P. Vanderkimpen, K. Van der Biest, J. Reyns, P. Peeters, W. Kellens, W. Vanneuville en F. Mostaert, 2008b. Overstromingsrisico's aan de Vlaamse kust. Evaluatie van de zeewering. Deel 1: Methodologie. WL Rapporten, 718/2A, Waterbouwkundig Laboratorium and Universiteit Gent and Soresma-Haecon, Borgerhout, België, 128 pp.

Visser, M., S. Batten, G. Becker, P. Bot, F. Colijn, P. Damm, D. Danielssen, D. Van den Eynde, L. Føyn, A. Frohse, G. Groeneveld, R. Laane, W. van Raaphorst, G. Radach, H. Schultz and J. Sündermann, 1996. Time series analysis of monthly mean data of temperature, salinity, nutrients, suspended matter, phyto- and zooplankton at eight locations on the North-West European Shelf. Deutsche Hydrografische Zeitschrift, 48, 3/4, 299-324.

Volckaert A. and R. De Sutter, 2009. Evaluation of climate change impacts and adaptation responses for marine activities (CLIMAR). Sector document - Coastal Tourism: Description coastal tourism along the Belgian coast. Arcadis Report N° CLIMAR_01. Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01A, Arcadis Belgium, Gent, 46 pp.

Volckaert A. and R. De Sutter, 2010. Evaluation of climate change impacts and adaptation responses for marine activities (CLIMAR). Sector document - Coastal Tourism: General study and evaluation of potential impacts of climate change on the Belgian Part of the North Sea. Arcadis Report N° CLIMAR_02. Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01A, Arcadis Belgium, Gent, 57 pp.

Volckaert A. and R. De Sutter, 2011. Evaluation of climate change impacts and adaptation responses for marine activities (CLIMAR). Guideline document. Arcadis Report N° CLIMAR_00. Report prepared in the framework of the CLIMAR project for the Belgian Science Policy, Contract SD/NS/01A, Arcadis Belgium, Gent, 58 pp.

Weisse, R., H. Von Storch and F. Feser, 2005. Northeast Atlantic and North Sea storminess as simulated by a regional climate model during 1958-2001 and comparison with observations. Journal of Climate, 18, 465-479.

Westtoer, 2008. Trendrapport KiTS Kust 2003-2008. 150 pp.

Westtoer, Toerisme Vlaanderen and Provincie West-Vlaanderen, 2009a. Investeren in een dynamisch kusttoerisme. Deel 2: Situatieanalyse, Brugge, 157 pp.

Westtoer, Toerisme Vlaanderen and Provincie West-Vlaanderen, 2009b. Strategisch beleidsplan voor toerisme aan de kust 2009-2014, Brugge, 295 pp.

Wikipedia, 2008. Artikels 'Dudzele', 'Lissewege', 'Oostkerke', 'Stalhille'.

Woestenburg, M., 2006. De paradox van de zwakke schakels. Landwerk, No. 6, 21-23.

Zurich Financial Services Group, 2009. The Climate Risk Challenge: The role of insurance in pricing climate-related risks. London, 16 pp.