Integrated water resources and coastal zone management in European lagoons in the context of climate change

This project is supported by the European Commission under the Environment (including climate change) Theme of the 7th Framework Programme for Research, under grant agreement nº [283157].

Final publishable summary report

PROJECT FINAL REPORT

Grant Agreement number: 283157

Project acronym: LAGOONS

Project title: Integrated water resources and coastal zone management in European lagoons in the context of climate change

Funding Scheme: FP7, Collaborative Project - Small or medium-scale focused research project

Period covered: **from** 01st October 2011 to 30th September 2014

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[1] Usually the contact person of the coordinator as specified in Art. 8.1. of the Grant Agreement.
[2] The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: http://europa.eu/abc/symbols/emblem/index_en.htm logo of the 7th FP: http://ec.europa.eu/research/fp7/index_en.cfm?pg=logos). The area of activity of the project should also be mentioned.

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1 Final publishable summary

1.1 Executive summary

Issue: The environmental issue of concern of the LAGOONS project was the anthropogenic deterioration (especially devoted to nutrient and eutrophication related substances) and climate change impacts - especially the effects of extreme weather events- on surface water and lagoons ecosystems. LAGOONS focused on an increased understanding of land to sea processes and the science-policy-stakeholder interface, all in the context of climate change, considering that (i) the successful management of coastal lagoons is dependent not only on scientific knowledge but also on the governance systems in which this knowledge is applied, and (ii) the importance of the interface between science, policy and stakeholders (including the citizens).

Objectives: The main objective of the LAGOONS project was: (i) to develop science-based strategies and a decision support framework for the integrated management of coastal lagoons and its drainage area; (ii) to enhance connectivity between research and policy-making in a lagoons context, which assures more efficient use of existing research results; (iii) to contribute to an effective implementation of EU water policies.

Methodology: To achieve the proposed objectives, the multidisciplinary scientific knowledge in the project group was combined and integrated with the knowledge and views of local stakeholders, using a participatory approach. With this innovative approach we developed integrated scenarios of future possible economic development and environmental impacts in four selected European coastal lagoons. These case study lagoons represent a set of "hotspot" coastal lagoons with a wide and balanced geographical distribution and different characteristics. The lagoons included are: Vistula Lagoon in Baltic Sea (a transboundary water between Poland and Russia); Tyligulskyi Liman Lagoon in Black Sea (Ukraine); Ria de Aveiro Lagoon in Atlantic Ocean (Portugal), and Mar Menor in the Mediterranean Sea (Spain).

Impact: In management terms, LAGOONS aimed to provide (i) pan-European management perspectives from various angles and methodological frameworks as well as the overall strategy recommendations from the four case studies, (ii) set of policy guidelines derived from the different analyses conducted in the project and proposes initiatives concerning management implementation in the case study areas all given in a local-regional-national-European setting.

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1.2 A summary description of project context and objectives

Historically, coastal lagoons have always attracted humans and supported their associated activities. They represent complex systems in which freshwater flowing from inland rivers meets the sea, creating a combination of fresh and salt-water and resulting in complex and highly productive, but at the same time fragile ecosystems. Taking advantage of their geographical location and natural resources, many of these systems have been utilised for fisheries and for collecting materials from plants, algae and animals for direct or indirect human consumption. They have also been used as harbours for vessels dealing with maritime trade. The natural capital of coastal lagoons, including the variety of ecosystem services and biodiversity are therefore essential for human well-being. In addition, coastal lagoons provide well-being not only to the people living around the lagoon but also to people living in inland areas, who may also be dependent on the trade and use of goods and services. At the same time they constitute important buffering zones between catchments and sea with respect to water quantity and quality. Due to this fact, they are subject to multiple stressors and have to cope with upstream loads and downstream influence from marine boarder, but also with weather events mmeaning that many drivers of pressures occurring within coastal lagoons, which integrate land-based and marine boundaries, influence their ecological and environmental status. Moreover, climate change combined with intense human activity imposes additional stress, and these disturbances occur concurrently over a range of spatial and temporal scales. The precise combined effects of this unprecedented change cannot be known, but the following challenges was identified:

- Coping with increasing water stress (quantity & quality)
- Reducing impact of extreme events (droughts & floods)
- Managing infrastructures vulnerable to climate risks
- Developing science-based innovative methodologies for enhanced lagoon resources management
- Developing and rank eco-innovative (engineering) technologies
- Promoting ecosystem services trade-offs
- Managing economical sector in spatial planning
- Promoting trans-boundaries options
- Promoting the ecoefficiency of new economic opportunities
- Promoting coastal lagoons economies' resilience to climate risks
- Promoting coastal lagoons ecological resilience to climate risks

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In general, the frequency of extreme hydrological events is expected to increase and this will affect all natural and man-made systems as well as human well-being. Climate change is also predicted to have a significant impact on the availability of ecosystem goods and services. There is a need to examine the risk of future losses of ecosystem goods and services and for using this knowledge to assist in the selection of appropriate management options. In this context, the management of aquatic systems, from freshwater, transitional waters to coastal waters, poses a number of challenges for policy-makers, decision makers, scientists and other stakeholders.

The main policy context of relevance for the LAGOONS project is the EU Water Framework Directive (2000/60/EC) and the activities related to its implementation in the Member States and in candidate countries. The focus of the LAGOONS project was to increase the connection between research and policy specifically related to transitional and/or coastal waters. However, coastal and transitional waters are affected also be the implementation of other relevant EU water legislation, namely the EU Marine Strategy Directive (2008/56/EC), the Integrated Coastal Zone Management (ICZM) recommendation (COM(2007)308 final, 7.6.2007) and the Habitat Directive (92/43/EEC). Some of the main goals foreseeing in the "Europe 2020 strategy" (COM (2010) 2020, 3.3.2010) should be attained through research and innovation taking into account climate change, whilst climate and resource challenges require common action taken. This means that there is a need for all Member States, to take into account different needs, different starting points and national specificities so as to promote climate change adaptation, capacity building and management.

In this context, the main objective of LAGOONS was to develop science-based strategies and a decision support framework for the integrated management of lagoons, based on an increased understanding of ***land-sea processes*** and the ***science-policy-stakeholder interface*** in the context of climate change.

More specifically LAGOONS sub-objectives were:

- To create a knowledge base of existing knowledge and data on environmental conditions in the four case study coastal lagoons as well as of relevant laws and policies governing coastal lagoons in a European context;
- To involve stakeholders and policy makers actively from the beginning to the end of the project;
- To conduct quantitative drainage basin modelling and to create scenarios for future developments in land-water interactions in coastal lagoons;
- To present and evaluate these modelling scenarios through a series of three stakeholder workshops in each case study area. These workshops enabled participation outside the scientific community and provided local knowledge and input into the refinement of the scenarios,

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- To develop strategies and decision support frameworks for pan-European dissemination and application. This was primarily based on the results of the scenarios as well as on the analysis of legal and policy frameworks, and of the actors and institutions active in coastal lagoon management.
- To up-scale the results produced in the four case coastal lagoons to management recommendations at pan-European lagoon scale.

To address this challenge we:

- formed a multidisciplinary consortium consisted of nine partner institutes from eight different countries (Portugal, Norway, Poland, Russia, Ukraine, United Kingdom, Germany and Spain; Figure 1.2.1); with a good background in integrated water resources and coastal zone management, legal policy and institutional analysis, climate change scenarios, hydrological and ecological modelling, ecology, spatial planning, toxicology and ecosystem services;
- selected a set of four costal lagoons (Figure 1.2.2) based on: that they must be measurable, if they were capable of reflecting the diversity of Member States coastal lagoons and if they were based on sufficiently reliable data to enable their comparison;
- ensured the stakeholders participation from the onset of the project, including an analysis of laws, policies and institutions;
- used scenario-building and modelling approaches to try and forecast the combined state of the four case study lagoons and its drainage basin, taking into account observed and anticipated changes in climate;
- applied the methodologies in the four case lagoons that support for Pan-European integration through a bottom-up approach;

Briefly the four selected case study lagoons are:

Ria de Aveiro, a shallow mesotidal lagoon, (45 km-long; 10 km-wide) located along the Atlantic Ocean on the northwest coast of Portugal and characterized by a temperate maritime climate;
Mar Menor – a microtidal lagoon (22 km-long; 9 km-wide), located along the Mediterranean sea on the south coast of Spain, and characterized by a warm-temperate dry climate;
Tyligulskyi Liman lagoon, a tideless lagoon (52 km long; 0.3 to 4.5 km wide) located in Ukraine on the southeast coast of the Black Sea and characterized by a temperate continental climate;
Vistula Lagoon, a non-tidal lagoon (91 km-long; 13 km-wide) located along the Baltic sea, partially on the coast of Poland and partially on the coast of Russia, and characterized by a maritime climate and continental climate.

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Figure 1.2.1 – LAGOONS consortium

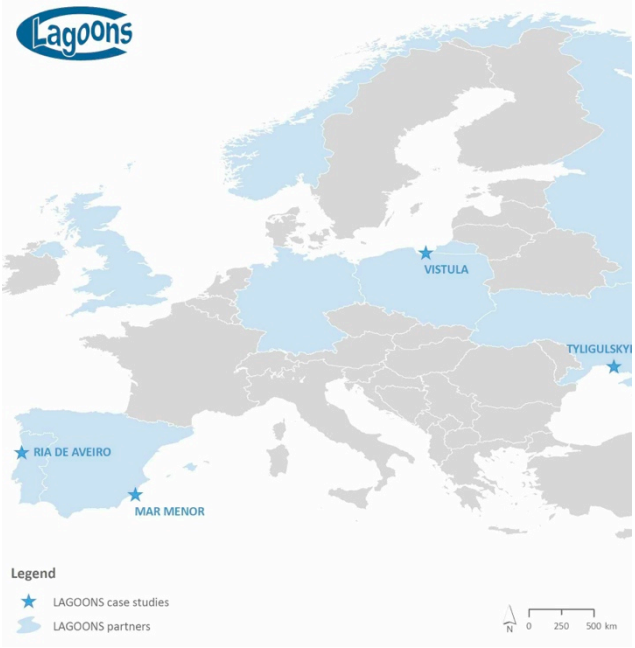

Figure 1.2.2 – Spatial distribution of LAGOONS case study lagoons

Having Vistula lagoon, a transboundary system, as case study, LAGOONS also created a platform that enables the development of strategies for a proper determination of common agreements between national legislation and international conventions, and the formation of suitable institutional contexts.

In more detail LAGOONS project had the following major features:

- A dedicated GIS knowledge platform managed the collection of metadata to assure a consistent flow of data and information for the project participants and for the external stakeholders;
- In-depth scientific analysis of pressuring issues identified by the stakeholders in each lagoon;
- Stakeholders were involved throughout the entire project, ensuring a strong focus on the science-policy-stakeholder interface;
- Focus on the catchments and lagoons interface, considering the processes from the catchment to the coast;
- Ecohydrological modelling of the drainage basin and its inputs to the lagoons;
- Hydrodynamic and water quality modelling of lagoons ecosystems;
- Development of scenarios together with local stakeholders (combining qualitative and quantitative scenarios);
- Case study and pan-European analysis of law, policy and institutions
- Up scaling of the case-studies results and dissemination to different audiences (Academics, Policy makers, stakeholders, including the citizens).

The concept of integrated, participatory, combined qualitative and quantitative scenarios for coastal lagoons is innovative and enabled us to better understand and manage the dynamics of the relationship between humans and the coastal lagoons in the context of environmental and climate change.

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1.3 A description of the main S&T results/foregrounds

The LAGOONS project achieved the Scientific & Technological target objectives, by: i) creating a GIS knowledge base platform for the selected case study (CS) lagoons available for the project participants and for the external stakeholders; ii) doing an analysis of laws, policies and institutions and effectively engaged stakeholders during the entire project, ensuring a clear ***science-policy-stakeholder interface***; iii) coupling catchment to coast modelling we increased the understanding of ***land-sea processes***; iv) applying the same methodology to the four selected case-studies, enabling to scale up the results and dissemination to different audiences (Academics, Policy makers, stakeholders, including the citizens); v) developing science-based strategies and a decision support framework for the integrated management of costal lagoons in the context of climate change.

More specifically the results on LAGOONS main activities are explained in the following:

1.3.1 webGIS knowledge base platform

An online GIS knowledge base has been created and can be accessed in the following address http://webgis.no/lagoons. This platform contains a short description of all CS lagoons (both in English and in each case study local language); digital maps gathered or produced during the project, namely from the science knowledge base (*see Deliverable D3.2*); diagrams; useful links to other existing platforms; and photo galleries. The GIS is developed in Open layers, which gives a user friendly, easy-to-learn application. The digital maps can cover the entire catchment to coast area (e.g. soil, land use, topography) or be more specific for the lagoon area (e.g. habitats, human activities). Results from the developed scenarios are also available as pdf-maps, illustrating e.g. the changes in land use, nutrient loads and water management.

From this platform it is also possible to download relevant information regarding each case study (CS) lagoon, namely: full reports about the current knowledge and knowledge gaps analysis for each CS lagoon (in English); and shorter versions technical briefs, also for each CS lagoon, both in English and in local language.

1.3.2 Stakeholder's engagement

The main concept underpinning the LAGOONS project was that knowledge produced via different scientific disciplines needed to be combined with local knowledge and stakeholders' views in order to produce integrated, participatory scenarios (supplemented by science modelling inputs) of possible future trends and conditions in coastal lagoons. Through a successful stakeholders engagement, LAGOONS facilitated the consideration of the project's scientific results, local community and overall policy interests in the formation, evaluation and adjustment of the integrated scenarios created to assess future management and policy options for the CSA in question (see *Deliverables D4.1 & D4.2*). Stakeholder's engagement was underpinned by a preliminary stakeholder and social group mapping

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exercise in order to identify the respective key groups (e.g. fisheries groups, community based organisations, farmer associations, industry representatives, conservation groups) within each of the four CS lagoons.

Stakeholder input was achieved through their engagement in three consecutive forms of active participation – Focus Groups; Citizens' Juries; Final stakeholder workshop (for more detailed information see *Deliverables D4.1& D4.2*).

The sequential engagement was perceived of training sessions for the LAGOONS scientific team to ensure the application of the same methodology in all CS lagoons, ensuring that they were conducted in a comparable way, and followed the subsequent temporal sequence:

- **Focus Groups** - were the first form of active stakeholder engagement used to ensure stakeholder involvement in the project and gain preliminary views. This initial form of 'opening up' information helped identify which, in the participants' minds were: the main features of the lagoon and any concerns regarding any issues or problems they had identified in relation to the lagoon, where they might be located and if so what future changes, if any, they would like to see in place.

The focus group (FG) results were used to make an informed choice on the following elements required for the citizens' juries, specifically: i) the relevant driving forces and their influence on each of the lagoons; ii) the fields of expertise that needed to be addressed and represented during the citizens' juries per lagoon.

- **Citizens' Juries –** were the second form of stakeholder engagement, a method of engagement and deliberation, which is based on the format used for criminal courts in the UK or US. The 'verdict' provided by a citizens' jury, based on the information presented to them by the expert witnesses, are informed choices regarding policy matters, in this case regarding each case study lagoon, unlike the verdict provided by juries in a court of law, where the verdict is either guilty or not guilty. To provide the 'verdict' the jury was asked to consider the future development of the lagoon in the next 15-20 years and to provide a series of recommendations in an attempt promote the future development of the lagoon according to the jury's criteria.

The citizens' juries (CJs) results were used to: i) identify the main messages from the individual CJs; ii) identify how the information and recommendations could further contribute to and expanded on the information received and already analysed via the FGs; iii) further define, expand or modify the content of the initial scenario storylines formulated after analysis of the focus group material.

- **Final stakeholder workshop** - The final part of the project's participatory process was a stakeholder workshop where the four scenarios per CS were presented and considered. The contents and outputs from the previous FGs and CJs were used to make an informed choice on the following elements required for the final stakeholder workshops regarding: i) the relevant

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driving forces and their influence on each of the lagoons; ii) quantification of the qualitative information presented in the storylines and their incorporation into the quantitative modelling by the project's modellers (from catchment to coast, see next section); iii) continuation of the iterative process for refining, defining and considering the content and aspect of the scenarios.

The qualitative storylines followed the methodology outlined by Gooch and Stålnacke (2006). The storylines used a matrix of four different possible futures. The aspects of the scenarios were high or low economic development and high or low environmental quality. These were used to produce the following four possible scenarios (up to year 2030), termed as:

- **Business as Usual (BAU)** – describes how the future could develop based on known changes and past trends, without any major deviation from present arrangements regarding economic growth or environmental quality.
- **Managed Horizons (MH)** – an alternative future where both economic and environmental factors are positively used to provide tangible human benefits but are co-managed in a way that not only does no harm but may also benefit the environment.
- **Set Aside (SET)** – a future, which may not provide direct tangible increases in benefits to the residents of the CSA but may provide indirect economic and environmental benefits to the area predominately through the value of and payment for ecosystem services and through ecological conservation.
- **Crisis (CRI)** – where both economic decline and environmental degradation of the study area impact on the well-being and livelihoods of the CSA residents and severely affect any economic, social and environmental recovery of the lagoon.

In the final workshops, stakeholders proposed recommendations to achieve the most desirable aspects and proposed recommendation to avoid the most undesirable aspects for each case study lagoon in 2030. These results for the four CS lagoons are summarized in a Multilanguage report available in LAGOONS web page (*Deliverable D7.2*).

The reasoning here behind the sequential engagement and inclusion of local participants in these participative and capacity building activities was that local inclusion can be beneficial to: increasing knowledge provision, exchange and creation; understanding and resolving or finding possible solutions to local issues regarding the future management of the CS lagoon (for more detailed information see *Deliverables D4.1& D4.2*). FGs, CJs and Stakeholder workshops technical briefs in local language are available in LAGOONS web page.

1.3.3 *Catchment to coast modelling*

Catchment to coast modelling results clearly shows that European lagoons respond differently to the imposed stressors, i.e. climate change, and combined climate with environmental and socio-economic stressors (see *Deliverables D5.2 & D6.3*).

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Catchment modelling

The main objective was to perform climate impact assessment and socio-economic scenarios (the four scenarios mentioned above) impact assessment for the catchment areas of four European lagoons: Ria de Aveiro, Mar Menor, Tyligulskyi Liman and Vistula Lagoon. For that, the eco-hydrological model SWIM (Soil and Water Integrated Model, Krysanova et al., 2000) was used.

Model set-up for catchments of four lagoons

The hydrological and water quality calibration and validation of SWIM in all four catchments was a very challenging task due to often poor and inconsistent data. Especially, water quality data were insufficient in spatial and temporal dimensions in all four cases. Nonetheless, after the standard calibration and validation for the main rivers in the catchments, SWIM was set-up for the total drainage areas of the lagoons. Despite of all difficulties, the results of model calibration/validation were satisfactory in all four cases, creating a sound basis for climate and socio-economic scenario impact assessment.

Climate impact assessment

A commonly used technique for impact studies at the catchment scale is to use climate scenarios from Regional Climate Models (RCM) as input for hydrological models. In our case a set of 15 climate scenario data provided by the ENSEMBLES project (van der Linden and Mitchell, 2009) was applied. The reference period was 1971-2000 (p0), and climate impacts were evaluated for three future scenario periods 2011-2040 (p1), 2041-2070 (p2), and 2071-2098 (p3).

The climate scenarios were evaluated comparing the long-term average monthly and annual temperature and precipitation in three future periods to those in the reference period. The averaged over 15 climate scenarios climate change signals for temperature are similar for all four case studies. They amount to 1.1°C for period p1, 2.2°C for period p2 and 3.2°C for period p3. Regarding precipitation, the projected signals are not so homogeneous in change direction, as for temperature, and the uncertainty in RCMs simulations is much larger. Until the end of the 21st century, an increasing trend in precipitation is projected for the Vistula Lagoon catchment, while decreasing trends are projected for the Ria de Aveiro and Mar Menor catchments, on average. However, in the case of the Tyligulskyi Liman there are large discrepancies between scenarios from different climate models, and on average only small changes in precipitation could be noted.

The results of climate impact assessment for our four case studies can be summarized as follows:

The patterns of change in water temperature and dissolved oxygen are the same in all four cases. The increasing trend in water temperature, by 2°C at the end of the century is clear, and the agreement between the scenarios is high. Dissolved oxygen concentrations show a small decreasing trend which is consistent between scenarios. The simulated results for other components differ between cases, and are shortly presented below case by case.

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RIA de AVEIRO - The results of climate change impacts on water discharge in the catchment of Ria de Aveiro catchment show a moderate decrease in the 1st and 2nd periods (-5 to -7%), which becomes higher in the third period (by the end of the century about -15% on average). Though the decreasing trend is very clear when average results driven by 15 climate scenarios are analysed, the uncertainty is high, and it is increasing with time from p1 to p3. All three nutrient components: nitrate nitrogen (NO_3-N), ammonium nitrogen (NH4-N) and phosphate phosphorus (PO_4-P) demonstrate the decreasing trends in all three future periods varying between -5% and -9% for NO_3-N river loads, between -3% and -7% for PO_4-P river loads, and between -6% and -18% for NH_4-N river loads on average, but the level of agreement between scenarios varies between periods and components.

MAR MENOR - The impacts for the Mar Menor are similar to that of Ria de Aveiro, as the climate change scenarios in these two regions show similar trends. The results show a moderate decrease of mean daily discharge to the lagoon by about 10% by the end of the century. For the 1st and 2nd periods the scenarios do not agree on a common trend, and on average only a small reduction <5% can be noted. The uncertainty of projections becomes higher towards the 3rd future period. For nitrate nitrogen some increase is projected for the first scenario period, and a decrease of about 20% is simulated for the middle and end of the century (periods p2 and p3). The other two nutrient components: ammonium nitrogen and phosphate phosphorus are decreasing, but very slightly.

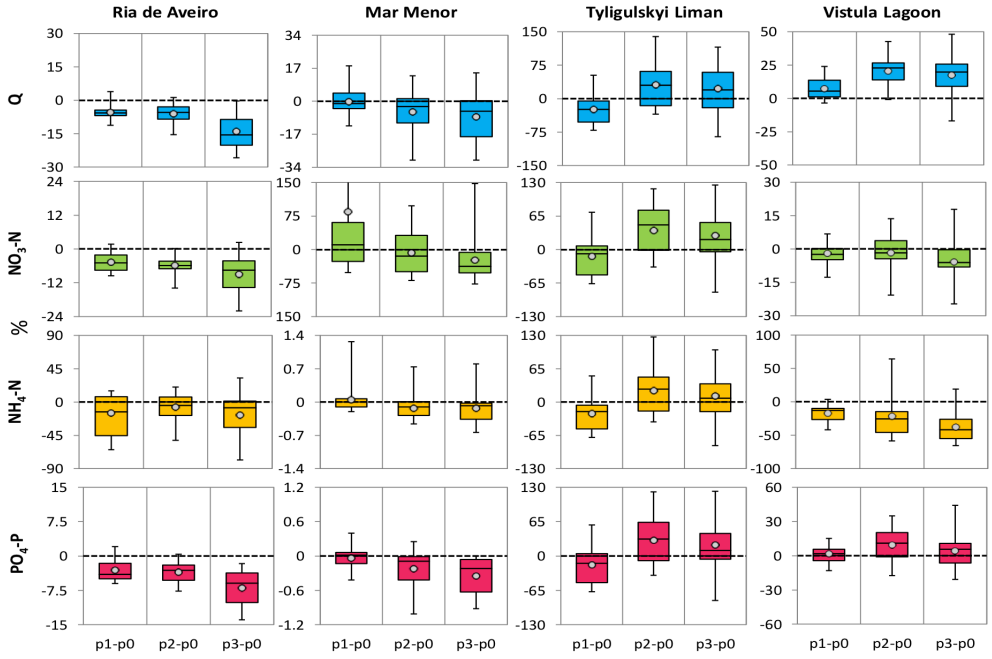

Figure 1.3.1 Percental changes in total water inflow (Q) and nutrient inputs to the four lagoons simulated with SWIM driven by 15 ENSEMBLES climate scenarios in future periods p1, p2, p3 compared to the reference period (p0). The box plots visualize min/max, 25/75-percentiles, median and average (dots) of percental changes per lagoon, variable and period.

TYLIGULSKY LIMAN - Water inflow to the Tyligulskyi Liman is strongly influenced by water management (filling of irrigation ponds) in the catchment. Water management was assumed to be unchanged for the future climate scenarios in this study. Though changes in precipitation are minor on

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average, river discharge as well as nutrient loads are expected to decline moderately in the first scenario period, but to increase in the middle and end of the century. The loads show a similar behaviour as river discharge.

VISTULA - The results of climate impact assessment on water flows in the Vistula lagoon catchment show a notable increase of water discharge by 7%, 21% and 18% on average in the three future scenario periods. Two nutrients: nitrate nitrogen and ammonium nitrogen demonstrate the decreasing trends in all three future periods varying between -2% and -6% for NO_3-N loads, and between -17% and -38% for NH_4-N loads on average. The level of agreement among scenarios varies between periods and components. On the contrary, phosphate phosphorus loads are expected to increase by 2 to 9% on average. The uncertainty ranges for this component are moderate.

The results of climate change impact assessment for the four case studies are presented in full in the *Deliverable D5.1*, for two single case study areas in Hesse et al. (2014) and Stefanova et al. (2014), and briefly shown in Figure 1.3.1. It is shown that the long-term average changes of total water inflow and nutrient loads entering the lagoons with uncertainty ranges based on results driven by all 15 scenarios for three future periods compared to the reference period.

Socio-economic and combined scenario impact assessment

For the assessment of potential changes in water quantity and quality for the catchment areas of the four lagoons, four storylines and qualitative scenarios were developed as described in section 1.3.2. Then these scenarios with short names Business as usual (BAU), Crisis (CRI), Managed horizons (MH) and Set-aside (SET) were translated into quantitative scenarios. To implement these scenarios, the following modifications of SWIM input data for each CS area and each scenario were necessary: a) development of new land use maps, and b) changes of some input parameters. The new land use maps were created using a GIS tool and certain criteria (see *Deliverable D.5.2*). Additional changes were made in the input data of SWIM, including the following: average annual loads from point sources, rates of water abstractions, irrigated area (Mar Menor), effective volume of ponds (Tyligulskyi Liman), and amounts of mineral and organic fertilizers. The impacts of the four socio-economic scenarios were assessed separately, as well as in combination with climate change for the period 2011-2040. Simulations driven by only one "best-fitting" climate change scenario from 15 were used for the combined scenarios, and the results were provided to the lagoon modellers to be used as input. The results are presented in full in the *Deliverable D5.2*.

Here we summarize only the combined impacts of climate change and socio-economic scenarios on the main model outputs and compare them between the four case studies. Figure 1.3.2 presents the long-term average annual changes in total water inflow (Q) and nutrient (NO_3-N, NH_4-N and PO_4-P) loads to the lagoons driven by the combined scenarios. The 3-dimensional plots allow comparing the impacts on a certain component (y-axis) between catchments (z-axis) and scenarios (x-axis). The

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relative changes are classified into four categories representing the strength of change: from a small impact below 1% up to a large impact between 51 and 100%.

The total water inflows to the Ria de Aveiro, Mar Menor and Tyligulskyi Liman are projected to decrease for each of the four scenarios, mainly as a result of decreasing precipitation in the future scenario period 2011-2040. The strongest decrease in water inflow is simulated for the Tyligulsyki Liman (which is different from the impacts of socio-economic scenarios only, some of which project an increase in water inflow). On the contrary, an increase in future precipitation in the catchment of the Vistula Lagoon leads to an increase in total inflow for the BAU, CRI and MH scenarios, whereas in the SET scenario this increase compensates the impacts of land use change, leading to practically zero changes in this case.

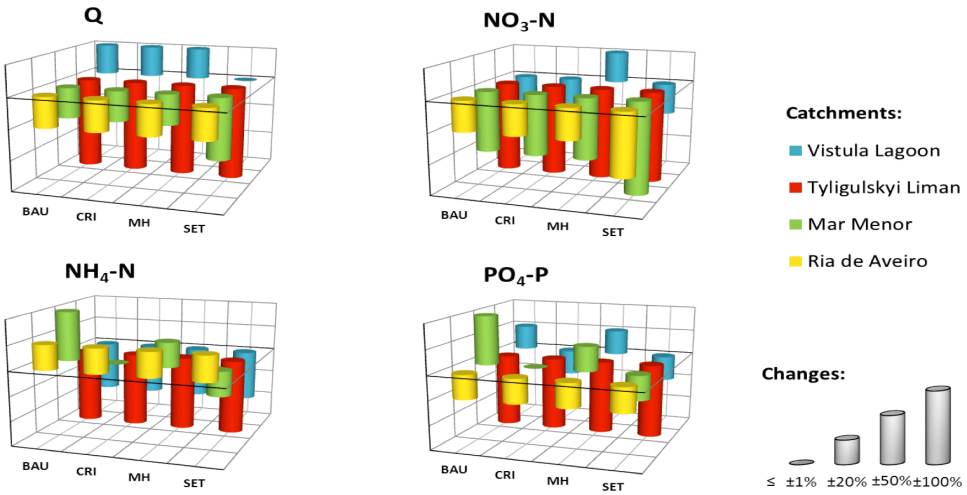

Figure 2: Summary of trends for discharge (Q), nitrate nitrogen (NO_3-N), ammonium nitrogen (NH_4-N), and phosphate phosphorous (PO_4-P) in the four case study areas caused by combined climate ("best fitting" climate scenario for the reference period 1971-2000 and the future period 2011-2040) and socio-economic (BAU, CRI, MH, SET) impacts.

The combined impacts on the total nitrate nitrogen load to the lagoons show a decrease for all scenarios and all four case study areas, except for the MH scenario in the Vistula Lagoon catchment. This can be related to both climate change (for the Ria de Aveiro, Mar Menor and Tyligulskyi Liman) and changes in management and land use (for all four case study areas). The significant increase in the applied fertilizer rates in the Vistula Lagoon catchment assumed for the MH scenario, combined with an increase in precipitation lead to an overall increase in the total NO_3-N load to this lagoon.

The simulated changes in the total ammonium nitrogen and phosphate phosphorus loads show divers patterns for the four lagoon catchments. The reasons for these trends are explained in details in Chapter 3 of *Deliverable D5.2*.

Despite of all the uncertainties connected to the combined climate and land use change impact assessment presented here, some general conclusions can be drawn:

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- Except for the Mar Menor catchment and the SET scenario in the Vistula Lagoon drainage basin, the impacts of climate change on water quantity are generally stronger than the impacts of the socio-economic changes;
- In general, the socio-economic changes have higher impacts on nutrient loads entering the lagoons than on the total freshwater inflow to the water bodies;
- The combined impacts on nutrient loads show diverse directions in three of the four catchments; only in the drainage basin of the Tyligulskyi Liman a decreasing trend in nutrient loads is projected for all socio-economic scenarios due to a strong climate change impact.

Lagoons modelling

The objective was to evaluate and estimate the lagoons response (water dynamics, water quality, biota and fish) to different climate scenarios based on results of climate and land based river discharges and nutrient inputs modelling performed for the catchments.

Model set-up for the four lagoons

In order to assess lagoons' response to climate change and different land-based river loads each of the CS lagoon set up and calibrated different sets of numerical models, namely: Delft3D-Flow (Deltares, 2014a) for hydrodynamics and Delft3D-WAQ (Deltares, 2014b) for water quality both in Ria de Aveiro and in Vistula lagoon; MOHID (Braunschweig et al., 2004) for hydrodynamics and water quality in Mar Menor; and OSENU-MECCA-EUTRO (Ivanov and Tuchkovenko, 2008) for hydrodynamics and water quality in Tyligulskyi Liman.

Climate scenarios for the four lagoons

Next, climate scenarios were selected according to the defined common methodology (for more detailed information see *Deliverables D6.1 & D 6.2*). In case of the climate change scenarios all CS selected 3 typical years representing following periods: 1971 – 2000 (p0), 2011 – 2040 (p1), 2071 – 2098 (p3) (with one difference for the reference period for Ria de Aveiro, 1981 – 2010) and in addition, each of the CS defined their own specific extreme climate scenarios relevant for the area and of high importance for the respective stakeholders. In an ideal situation, the lagoon models should have been ran for all considered climate periods (p0, p1, p3) and next the modelling results would have been analysed with respect to typical and extreme climatic and hydrodynamic situations. However such approach was not possible to follow in approximately a year time that remained in the project for the lagoons modelling, therefore some less time consuming solution was chosen. More precisely, we selected 'typical' years from each climatic period, as well as extreme ones, namely: hot summer in Ria de Aveiro; hot summer, cold summer, wet year and dry year in Mar Menor; hot summer and cold winter in Vistula lagoon; and high-water (moist) year, low-water (dry) year in Tyligulskyi Liman (For more detailed information see *Deliverable D6.3*).

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Climate impact assessment

Details on climate changes impact on lagoons are presented in *Deliverable D6.3*. Here some general brief results are given.

RIA de AVEIRO - The moderate changes in freshwater and nutrient inputs from the catchment together with the short flushing times of Ria de Aveiro results in a limited variation of both nutrients and chlorophyll a between present and future scenarios. In this way, the differences highlighted above will tend to reflect the interannual variability more than a sustained change between climate periods. On the other hand, the exposure to changes at the oceanic boundary will increase due to the rise in sea level, which is expected to increase the exchange between the lagoon and the ocean. An example of this is the projected drop of water temperature and rise in salinity. Projections for the Northwest Iberian coast for the end of the century point to a rise in coastal upwelling caused by the increase of equatorward winds. The enhanced exchange between the lagoon and the adjacent continental shelf will incorporate more of the deep water than before leading to cooler and saltier conditions. The Hot Summer scenario showed that although there was no significant change in water temperature, for the end of the century the low freshwater input usually associated with exceptional hot weather would favour the rise in salinity in the Ria de Aveiro.

MAR MENOR - For the Mar Menor, the climate change impacts are expected to have severe consequences in major hydrodynamic and water quality parameters defining the current functioning of the lagoon. The rise in sea level is going to cause a marked decrease in water residence times. In this hypersaline lagoon, and despite the parallel increase in water temperatures (and therefore evaporation rates), this will be translated into a decrease in salinity, since this parameter is mostly defined by the amount of water that enters the lagoon from the Mediterranean Sea and not by the amount of freshwater inputs that are extremely low and are expected to decrease. A similar event occurred during the early 70s after the enlargement of El Estacio channel and caused the colonization of the lagoon by Mediterranean species as salinity ranges became less extreme. This future "Mediterraneanization" of the lagoon might have unexpected consequences for the functioning of the entire lagoon and the support of valuable ecosystem processes and services. Equally (if not more) important is the expected impact on *C. prolifera* distribution and survival. As predicted by Lloret et al. (2008), the increase in summer temperature as a consequence of climate change will cause a deleterious impact on macroalgal beds in the Mar Menor. The impact goes beyond the death of huge masses of the algae and will have a profound effect on the ability of the benthos to process nutrients and, therefore, on ecosystem resistance to eutrophication (Lloret and Marin, 2009; Lloret and Marin, 2011). Although the models predicted a recovery phase for *C. prolifera* biomass after the summer in the modelled scenarios for the last years of the century, this situation is very unlikely to happen, since other 'undesirable' macroalgal species are likely to occupy the empty niche, limiting *C. prolifera* re-colonization and causing the collapse of the system.

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TYLIGULSKYI LIMAN - For the Tyligulskyi Liman lagoon, its biodiversity and fish productivity during the period p1 will be endangered by the gradual increase in the water salinity up to the mean values of 30–40 PSU. The increase will arise from the reduction in the freshwater inflow into the lagoon. Nevertheless, the mineral nitrogen compounds will limit the production of organic matter by algae. During the period p2, the increasing freshwater inflow will diminish the problem of water salinity. However the additional input of mineral nitrogen will enlarge the primary production of organic matter; as a result, eutrophication with all its negative effects, e.g. hypoxia and anoxia, is likely to occur. Moreoever, high evaporation rates will be observed during the period p3. This will result in decreased inflow of sea water that together with the changed mineral nitrogen inputs can deteriorate ecological conditions in the southern part of Tyligulskyi Liman.

VISTULA - For the Vistula Lagoon the climate change impacts are expected to have moderate consequences for hydrodynamics and water quality parameters in typical years. The expected salinity decrease in the lagoon, mainly due to salinity reduction in the sea, and temperature increase in combination with moderate changes in loads will result in keeping similar ecological status of the lagoon. More pronounced consequences can be expected in extreme cases. After a cold winter spring floods can be expected leading to significant water exchange in the lagoon and resulting in an increase of P04-P concentration. In years with hot summer when both river discharge and water temperature are expected to increase, the latter seems to be the dominant. It can be expected that joint decrease of salinity, ammonium and nitrate concentrations can lead to limited growth of phytoplankton during the whole vegetation period. However, a transfer of the ecosystem to nitrogen limitation can intensify bluegreen algae blooms due to phosphates availability in the water column and nitrogen in atmosphere.

Socio-economic and combined scenarios impact assessment

Following the defined common methodology, and in order to assess lagoons' response to different environmental and socio-economic possible future scenarios for the year 2030 (for more detailed information on the scenario story lines see Deliverables D4.2), modelling was performed for the typical year from the period 2011 – 2040.

Results of how the lagoons may cope with multiple stresses originating from the climate change impacts and socio-economic and environmental changes in the catchment were in detail presented in Deliverable D6.3. Models of all four lagoons were run with the same set of scenarios, with story lines specific for the area and described in Deliverable D4.2.

In general, the lagoons' responses to socio-economic scenarios were moderate to small (Figure 1.3.3). The greatest changes (up to 25%) were predicted in the Vistula Lagoon and the least in the Tyligulskyi Liman (less than 5%) and Ria de Aveiro (from 8% to -21%). Changes in nutrients concentrations and chlorophyll a were minor and did not exceed 25% in all the lagoons. These changes seemed to be related to the fresh water inflow from the catchment modified by different water use, land use and

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management in the catchment according to assumed scenarios and comparing to the reference period (For more detailed information see Deliverables D6.3).

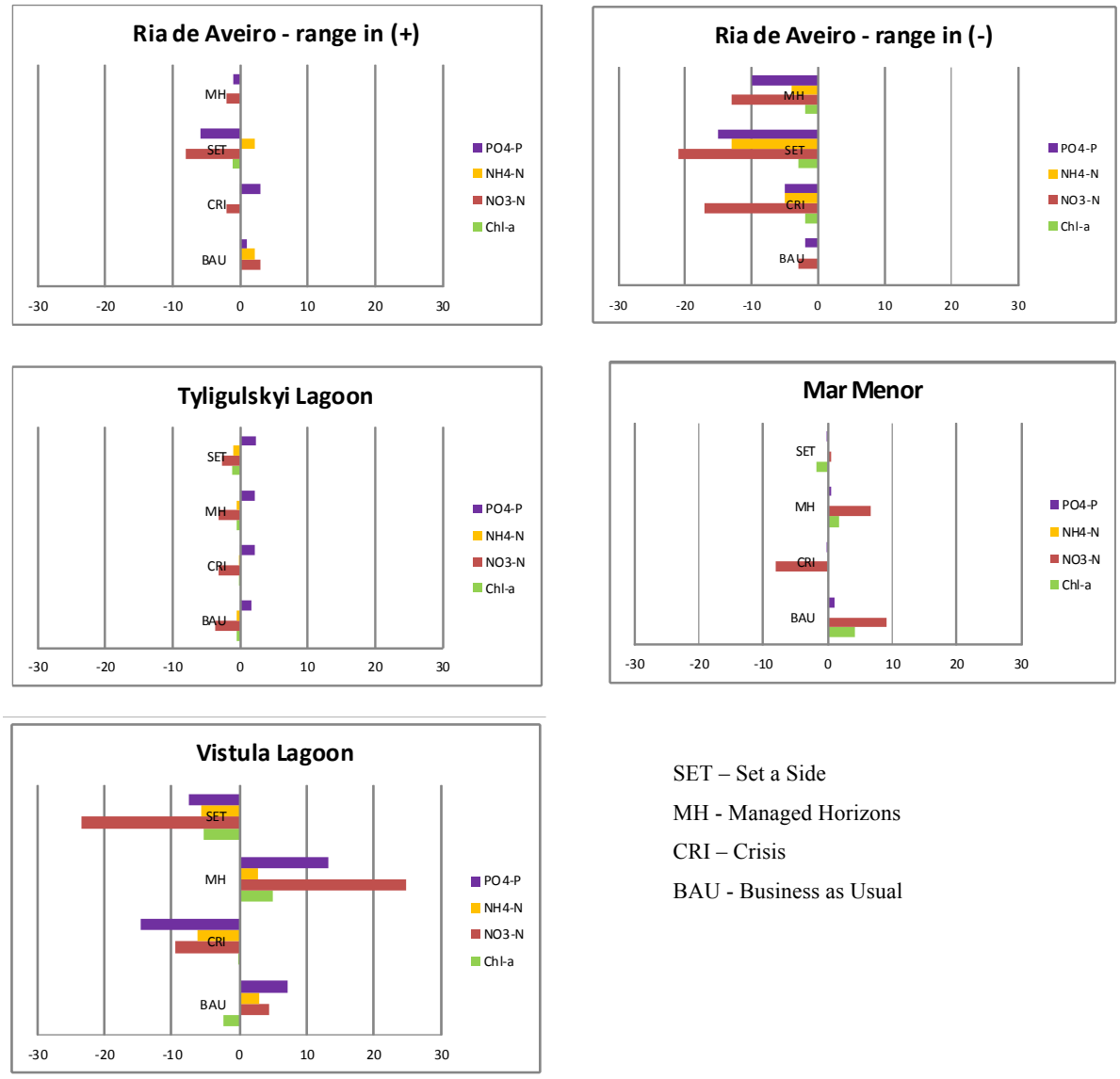

Figure 1.3.3 – A summary of the environmental impacts on the socio-economic and environmental scenarios (For more detailed information on the scenario story lines see *Deliverables D4.2*).

1.3.4 Scaling up the results from the selected lagoons

The applied bottom-up approach based on four selected lagoons allowed us to scale up the results, underpinning dissemination to different audiences (academics, policy makers, stakeholders, including the citizens). The applied CS scenario analyses in a medium long-term perspective and an analysis of trends, threats and opportunities in which the question of compatibility of ecosystem services and social-economic interests was crucial in this respect. Such an analysis enabled a proactive approach rather than a reactive one, and the so-called SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) allowed us to do so in a rational and concise manner. This analysis is commonly used to

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analyse and diagnose the state of the environment in order to define the guidelines for a strategic environment approach. It can be used to analyse the position of environmental conservation and management in comparison with public policies, sectorial strategies and/or programs. In terms of coastal lagoons management the objective of applying this analysis was to identify and capitalize the Strengths; minimize or overcome the Weaknesses; follow the Opportunities and adapt and/or mitigate the Threats. In the LAGOONS project the information used for the SWOT analysis in each CS lagoon, was existing knowledge on the lagoons' physical, chemical and biological characteristics (see *Deliverables D2.1, D2.2, D3.2, D5.2 & D6.3*), combined with expert knowledge and the stakeholders perception, including the local population. This was achieved as a result of a sequence of participatory meetings, which included focus groups, citizen juries and stakeholders workshops (see *Deliverables D4.1& D4.2*).

In a Pan-European perspective the SWOT analysis showed that coastal lagoons have:

- **Strengths**: Natural Capital, biodiversity and tourism potential;
- **Weaknesses**: the untreated waste water inputs and/or potential for eutrophication, and uncoordinated management;
- **Opportunities**: EU Directives; RTD (Research and technological development) activities and tourism;
- **Threats**: climate change, environmental pressures and conflicting activities.

In addition to the SWOT analysis, the generic DPSIR framework (Drivers, Pressures, State, Impacts, Responses) enabled the understanding of the complex relationships between the driving forces on coastal lagoons and their impacts, facilitating the society's responses to them. The methodological approach also combined the different scientific disciplines in a multidisciplinary approach, including the existing quantitative-qualitative information from current scientific knowledge but also the knowledge from the local population.

The DPSIR framework highlighted several drivers common to all the lagoons, although the resulting pressures changes for each lagoon was depending on the specific socio-economic development in each of the regions. The common identified drivers can be summarized as follow:

- **Drivers** (anthropogenic) - Population density and growth, Tourism and related activities, Harvesting activities, Natural resources demands, Connection to sea infrastructure and maritime transport, Industry and related activities (mining extraction included), Uncoordinated management/ insufficient transboundary cooperation, Economic crisis;
- **Drivers** (Exogenic unmanaged*) - Natural characteristics of the lagoon (e.g. ecohydrology and geomorphology); Invasive species; Unbalanced natural biological populations; Coastal erosion; Extreme weather events, Global climate change (e.g. sea-level rise, global warming, altered patterns of precipitation);

  * Means that local management cannot address the causes of change, only the consequences

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For Pan-European up-scaling and integration we applied a Nested-DPSIR with each sub-cycle starting from each identified driver. Responses for the management of each CS lagoon necessarily need to address causalities between different drivers, which are the basis of the nested-DPSIR approach (Atkins et al. 2011). Therefore, for each CS lagoon we propose a series of recommendations taking into account all the identified drivers. In a pan-European perspective, some of these recommendations were common, however more important than the general recommendations are the specificities of the measures proposed. These have deliberately been proposed taking into account the specific ecological and socio-economic aspects of the lagoons' ecosystem services, in the context of economical and environmental change.

1.3.5 Management recommendations

The LAGOONS novel approach enabled to integrate the stakeholder's views and expectations into the decision support framework and recommendations. The Pan-European integration aspect ensured that the project results are particularly useful for the connectivity between research and policy-making, and science-policy interface in support of the common implementation strategy of the Water Framework Directive, and other water and environmental related EU policies (see section *1.4 – Potential impact*).

In the context of the "*Europe 2020 strategy*", defines "*A strategy for smart, sustainable and inclusive growth*" (COM (2010) 2020, 3.3.2010), it was seen from scaling up the results from the selected lagoons, that tourism represents a present Strength and an Opportunity for the future, being also recognized as a benefit that can be capitalized and followed. Tourism is seen as a priority sector for the EU sustainable economic development (COM(2014) 85 final, 2014/0044), since it is an activity with continuous growth in Europe, and in this sense tourism can also be considered an important driver for coastal lagoons. In fact, in a pan-European perspective the seasonality and the unregulated tourism practices are some of the concerns of European stakeholders, which recognized the importance to turn touristic activities sustainable along the whole year. This goal is part of the desired vision that considers the state change to be achieved by 2030. At the same time, European stakeholders recognized the importance of a healthy ecosystem for the maintenance of human activities and wellbeing.

In LAGOONS we have identified several short-coming and challenges that the management communities need to better emphasise. Our recommendations are as follows:

- There is a need for better linkage between environmental conditions (and data) with socio-economic variables particularly across the sea-land interface in the context of spatial management;
- Effective lagoons management critically depends on high-quality data, particularly comparable water quality data, uniform pressure data and harmonised data in geospatial format;

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• There is a lack of clear administrative responsibility for the implementation of coastal lagoon management and an absence of commonly agreed objectives and timeframes in which these objectives should be achieved. A better coordination of the work of the authorities involved in the management of the lagoons is recommended.

All the four lagoons studies are managed within a complex legislative and policy context, with a wide variety of institutions and actors involved in the use and management of the lagoons. It is therefore necessary to develop a framework of common objectives and management guidelines in order to promote a more sustainable development in the areas and protect its natural resources and biodiversity, especially facing the expected consequences of future global climate change.

To conclude, there is a need to create an integrated vision for all European coastal areas and its drainage areas. More specifically there is a need for better sectorial of all waters related to a lagoon and for a single coordinating unit for coastal zones management. Openness around data and information sharing is also needed in order to include citizens and stakeholders into the management of the lagoons. The science-policy interface should be improved and it is also necessary for better recognition of the connectivity from land, streams, rivers, lagoons and coastal zones.

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1.4 The potential impact

In management terms, LAGOONS provides (i) pan-European management perspectives from various angles and methodological frameworks as well as the overall strategy recommendations from the four case studies, (ii) set of policy guidelines derived from the different analyses conducted in the project and proposes initiatives concerning management implementation in the case study areas all given in a local-regional-national-European setting. In this section we will present the potential impact seen from each case study perspective and from the context of three pan-European perspectives: Policy, Environment and Modelling.

1.4.1 Case studies

RIA DE AVEIRO – The potential impacts of the project to the integrated management of Ria de Aveiro will be addressed considering the new scientific knowledge, the participatory processes and the proposed recommendations.

Contribution to scientific knowledge base

During the last two decades the Ria de Aveiro has been the subject of several studies covering multidisciplinary topics. However, there are still several open questions, which gives rise to the need for further research, including changes in the lagoon ecohydrology and the resulting impacts in Ria habitats that support a high biological diversity. In this context the project provides a legacy of information available at LAGOONS web page for Academics, Policy makers and environmental managers, namely: i) updated information on Ria ecology (e.g. seagrasses and saltmarshes), ecosystem services (e.g. identification and mapping), and environmental threats; ii) catch estimates and bioecomomic analysis of bait digging; iii) systematized information on the fauna and flora of the Ria, including invasive species; iv) catchment to coast impact of climate on hydrology and water quality of Vouga river and Ria de Aveiro lagoon; v) catchment to coast impact of combined environment and socioeconomic scenarios for the year 2030 (considering the typical climate for the period: 2010-2014) in hydrology and water quality of Vouga river and Ria de Aveiro lagoon.

Outputs from the participatory process

One of the major impacts towards the integrated management of Ria de Aveiro is the fact that the stakeholders involved in the LAGOONS participatory process allowed to bridge the gap between academics and stakeholders. It also allowed academics to internalise stakeholders vision for Ria de Aveiro, and stakeholders to actively participate and follow their contribution to the scientific knowledge. The experience was publicly acknowledge, by both, LAGOONS team (academics) and the stakeholders (policy makers, environmental managers and ordinary citizens), at the workshop organized to present the final results and recommendations for the integrated management of Ria de Aveiro.

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Recommendations

The multidisciplinary approach and the active participation of stakeholders proved to be central in identifying the 'driving forces' and 'opportunities', needed for the formulation of recommendations to achieve the desired and chosen vision for Ria de Aveiro. The project results and stakeholders recommendations summarized in the report *LAGOONS (2014) Gestão integrada de lagunas costeiras europeias no contexto das alterações climáticas: A Ria de Aveiro. (Integrated water resources and coastal zone management in European lagoons in the context of climate change: The Ria de Aveiro) [Lillebø AI (Eds.)] 60 pp.* (in Portuguese) has been acknowledged by the Portuguese Environmental Agency (Agência Portuguesa do Ambiente, I.P. - APA).

VISTULA – The potential impact of the LAGOONS project in the Vistula Lagoon region is addressed from the Polish and the Russian perspectives, considering the new knowledge, the participatory processes and the recommendations. In addition, the potential impact in a transboundary perspective is also highlighted.

The transboundary perspective

The project contributed to gaining new knowledge mainly concerning impact of the climate and socio-economic and environmental scenarios on the lagoon water environment. Analysis of result of computations of different scenarios indicated that climate impact on the lagoon will be more significant than the socio-economic and environmental one according to the selected scenarios. With regard to climate change impact the main message is that it will result in desalinization of the Vistula lagoon waters in future due to expected decrease of salinity in the Baltic Sea and also increase of fresh water discharges from the catchment. Regarding the nutrients their concentrations will decrease (NO_3-N, NH_4-N) with the exception of PO_4-P, which will increase. This will result in possible increase of algal blooms in the lagoon and the lagoon could likely become nitrogen limited nitrogen limited. Results of the socio-economic and environmental scenarios indicate that the lagoon's response to socio-economic scenarios was moderate. The greatest changes in nutrients and chlorophyll-a concentrations were of up to 25% in case of NO_3-N: as an increase in case of Managed Horizons (MH) scenario and as a decrease in case of the Set Aside (SET) scenario. The MH scenario happened to be the least desirable one. The next least desirable scenario was the Business-as-Usual (BAU). The SET and Crisis (CRI) scenarios were the most desirable scenarios with the greatest nutrients reductions in the lagoon.

The new knowledge can also be related to application of the methodology proposed for the participatory process, as it was not used in that form before in Poland and Russia.

Implementation of the participatory process proposed in the project resulted in gaining a lot of new knowledge on the situation in the Vistula Lagoon, both environmental and socio-economical. Local communities got involved in the process and they also had a chance to interact with experts and decision makers. That allowed for free exchange of opinions and ideas and improved the local dialog.

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LAGGONS have also cooperated with FP7-project ARCH in terms of joint work on a MANAGEMENT PLAN FOR THE VISTULA LAGOON REGION, which was presented at the Final Workshop (at which Polish and Russian stakeholders participated). This report was delivered local Polish authorities and representatives of the local communities. There are good chances that the Plan will be followed up and at least some part of it will be implemented soon. It may also be used in the future as an example for the Russian side of the lagoon.

Recommendations for further (beneficial for the lagoon) Polish / Russian activities have been worked out. They comprise following actions described below.

A joint Polish / Russian monitoring program should be implemented (with sampling at the same dates, pre-agreed spatial monitoring design and scope of monitored atmospheric, hydrological and environmental parameters – consistent sampling rates, dates and spatial coverage) as a key tool for water quality status and trends assessment, and planning of actions. The same modelling tool for water quality assessment should be implemented in a consistent manner in the both national parts of the lagoon. Identification and documentation of present water uses, analysis of internal and potential conflicts in water use are essential steps for maritime spatial planning. Identification of ecosystem services and their beneficiaries from both sides is needed in order to manage the lagoon more effectively. Regular meetings of the transboundary commission (or other trasnboundary bodies) in small towns around the lagoon (co-chairman from both sides) are recommended. Efforts are needed on harmonisation of environmental legislation and acceptance of mutual Code of Conduct or Best Practice Recommendations as a supplementary tool for national legislative systems. A Public Lagoon Forum (as, for example, the Forum of the Vistula lagoon) should be established as a platform for wide public discussions of the joint problems (meetings every year or 2 years). Support for joint research project activities and regular reporting about projects achievements to the Lagoon Forum is also suggested. Moreover, wide involvement of practitioners and public in setting the goals for those research projects (may be open call on the basis of local and international financial resources) is recommended. Finally, a website dedicated to the lagoon problems (both local languages + English) permanently supported by local and international resources should be established

The Polish perspective

Extensive studies on economic rationale of the cross-cut throughout the Polish side of the Vistula Spit are required. Preparation of environmental impact assessment of crosscut or any other canal design including possible transboundary influence on the construction and operation phases is recommended. Emissions from more intensive agriculture should be studied and inspected (e.g., by monitoring). Implementation of flood risk policy should be conducted bearing in mind engineering, ecological and socio-economic aspects.

The Russian perspective

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In the Russian part of the Vistula Lagoon, the salt water intrusions were studied from two perspectives: (a) as a consequence of climate changes in atmosphere forcing and watershed influence, and (b) as a consequence of anthropogenic modification of physical characteristics of the lagoon, which may influence a lagoon system in a scale of climate variations. More precisely the LAGOON project focused on: i) the impacts of the probable intensification of saltwedge intrusion upstream the Pregolia River and increase of frequency of the events of blocking the intakes of the City Water Supply System by this intrusion; ii) salinization of the Vistula Lagoon due to construction of deep water Port in the Vistula Lagoon area.

The main socio-economic impact of the LAGOON project was the clarification that the threat of increasing of frequency and intensification of deep saltwedge intrusion upstream the Pregolia River (main tributary of the Vistula lagoon) are rather not expected in the future, at least not due to climate changes. In general such intensification is possible, but it may be caused by human intervention – the construction of deep-water harbour in the Vistula Lagoon. This construction may not lead to salinization of the lagoon area, but to an increase of maximums of water level rise during storm surges (South-East and East winds), and therefore increase of flood probability.

The public in the Kaliningrad Oblast was informed about the LAGOON project via several publications in the newspapers and two dissemination events: i) Multi-stakeholder seminar "Local climate change and needs for basin-related adaptation", organized in the framework of the projects LAGOONS and NEMAN - "River basin management and climate change adaptation in the Neman river basin", in 21-22 January 2014 in Kaliningrad. Representatives from regional and federal environmental authorities (Kaliningrad Oblast of the Russian Federation and Republic of Belarus), industry and consulting firms, scientific and education organization (from Kaliningrad Oblast and Poland), participated; ii) The Vistula Lagoon Forum - the First International Forum dedicated to sustainable use of water resources in the Vistula Lagoon sub-region, which was held 13-14 of May 2014. The LAGOON project as associated partner of the Forum expressed its support and contributed to the Forum (more details and the Forun resolution are available at LAGOONS web page).

MAR MENOR – The potential impacts of the project to the integrated management of Mar Menor lagoon will be addressed considering the new scientific knowledge, the participatory processes and the proposed recommendations.

Contribution to scientific knowledge base

The loss of benthic macrophytes and the appearance of eutrophication processes could drive to a significant decrease of habitat quality in the lagoon with unexpected consequences to the biological diversity of its communities. If climate change predictions become true, the current status of the Mar Menor lagoon is advocated to collapse, resulting in a profound deterioration of the whole ecosystem through the appearance of eutrophication processes with higher nutrient concentrations, the proliferation of phytoplankton and floating macroalgae or even more serious phenomena, such as

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hypoxia, affecting not only the biological communities but also the main local economic activities, fisheries and tourism.

The analysis of recorded environmental variables confirmed the existence of strong environmental gradients in the study area. These gradients seem to have a small influence on macrobenthic species distributions that are mostly defined by the organic matter content of the sediments and the presence of *C. prolifera*. The existence of a well developed bed of the macroalga is allowing the settlement of this benthic community and its survival is determined by the presence of C. prolifera in the lagoon. Temperature also has a very strong influence on the community structure. The extremely high temperatures of the summer have a clear effect on benthic species abundances, causing an impact on benthic community structure. It is likely that future increases of water temperatures or longer warmer seasons in the area as a consequence of climate changes may originate a severe impact on these communities and the processes and services they support

Outputs from the participatory process

Three stages of the participatory process allowed to bridged the gap between the different drivers of Mar Menor and academics. Due to the heterogeneous viewpoints and interests related to Mar Menor we could appreciated the main picture of the principal concerns of stakeholders. On the other hand, experts from the university and other regional institutions offer the stakeholders a full knowledge on several different fields. Hence, as a result of the methodologies acquired during the project, it was possible to foster the participatory process and data analysis providing concrete recommendations for future management of the Mar Menor.

Recommendations

After three years of project and multidisciplinary approach, a global point of view of the Mar Menor main problems were obtained. Thanks to this project, it has been possible to foresee a future scenario of the lagoon under climate change conditions. In addition, the presence and distribution of the main species and effects of temperature changes on biomarkers were foreseen. The stakeholder's results provide us the clue to know the future activities that will develop in the Mar Menor. Furthermore, we have obtained the instruments and recommendations for the proper management and planning of all these probable activities. The results and recommendations of the project have been exposed to the Regional Administration of Murcia (Consejería de Agricultura y Agua: Servicio de Fomento del Medio Ambiente y Cambio Climático).

TYLIGULSKYI LIMAN - The project allowed demonstrating for public authorities, local government and public at large that the Tyligulskyi Liman Lagoon is the unique natural system with numerous natural resources, which can be used for the purpose of socioeconomic development of adjacent territories in Odessa and Mykolaiv regions of Ukraine in the scope of recreation, ecotourism, health-care, aquaculture and regulated fishing. The ecological system of the lagoon is of great

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importance for the support of biodiversity in this area. Therefore, the pressing problem is to preserve and to use rationally its natural resources under the climate change.

The public discussion was devoted to the scenarios of future socioeconomic transformations in the Tyligulskyi Liman Lagoon area and was realized as focus groups, a citizens jury and stakeholder workshop. This discussion has revealed some problems and positive aspects as well as has resulted in the certain scenario of future socioeconomic situation – 'Managed Horizons'. This scenario assumes the direct sustained growth of various preferences for local residents, the development of industries that are typical for the region, as well as competing views on uses of the landscape park and the configuration of the channel. It was also revealed that very complicated, but inefficient management is the factor affecting negatively on the ecosystem sustainability and worsening the quality of water recourses in the lagoon. Other negative factors are the unregulated land use and the violation of the Water Code of Ukraine concerning the restricted economic activity within the water protection zones and coastal protective strips in both the lagoon and its drainage basin. The unbalanced socioeconomic development and ecological problems in the Tyligulskyi Liman Lagoon are conditioned to a large extent by the violation of the basin management model that is one of the main requirements of the Water Framework Directive in the nature resource management. For Tyligulskyi Liman, the implementation of basin management model has to stipulate the development of the plans for its water and ecological management, and the results of the LAGOON project will be assumed as a basis for these plans. The Odessa Regional Council has made first steps in this direction. For example, the working team in the Odessa Regional Council was officially created in the February 2014 in order to develop measures for the recovery of water balance in Tyligulskyi Liman. In the April 2014, this working team reaffirmed the worsening ecological status of the lagoon and advised the Odessa Regional Council to include the ecological examination of situation in Tyligulskyi Liman into the list of activities that can be sponsored from the regional ecological fund. Also, it was decided to develop a project feasibility study for the reconstruction of connecting channel and for a substantiation of its operability.

The results of the LAGOON Project were presented for the implementation into the activities of Odessa Regional Water Management Department, Department of Ecology and Nature Resources in Odessa Region State Administration, Standing Commission in charge of Ecology, Nature Management and Emergency Prevention in Odessa Regional Council, Tyligulskyi regional landscape parks in Odessa and Mykolaiv regions.

The problems of water and ecological management in the Tyligulskyi Liman Lagoon are similar to those are intrinsic for other lagoons in the Northwestern Black Sea area (e.g., seventeen lagoons are located in the Odessa region). These problems, including results of the LAGOONS Project, were discussed on Ukrainian Scientific and Practical Conference "Limans of Northwestern Black Sea Area" that was held in 2014 in Odessa State Environmental University. The resolution of the Conference

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contains the proposition to the Odessa Regional Council to develop and to implement "The regional Programme for Preservation, Restoration and Rational Use of Natural Resources in Limans of Odessa Region".

1.4.2 Policy

The Lagoons project adopted an innovative and participatory approach to the formulation of policy recommendations, both for the individual case areas as well as for policy from a European perspective. The results of the project demonstrate that this approach is feasible and productive; the stakeholders and members of the public that contributed to the formulation of alternative futures through the scenario exercises were able to produce informed recommendations based on a combination of scientific and lay knowledge.

The potential policy impact of these results is in the formulation of future strategies to formulate sustainable strategies for coastal lagoons and other ecosystems. It has been demonstrated that the three-stage participatory methodology used in the project could be successfully utilised in a number of different geographical, political and administrative contexts. Further development of the method could lead to the introduction of a methodology for European ecosystems that involves stakeholder and the public in the decision-making and implementation processes, processes based on informed input and recommendations.

The major potential policy impact of the project is therefore in the combination of participatory methods used, and their ability to meet the expectations of EU policy for stakeholder and public participation in the environmental policy process.

1.4.3 Environment

Regarding environment, LAGOONS aimed to contribute to an effective implementation of EU water related policies. When looking at lagoons environmental management, in the frame of catchment to coast processes under the context of climate change, several policies are to be taken into account, namely:

- Water Framework Directive (WFD) (aims that all surface waters achieve a '*good ecological and chemical status*' by 2015);
- Marine Strategy Framework Directive (MSFD) (aims for marine waters to achieve or maintain a good environmental status by 2020 at the latest);
- Floods Directive (aims to reduce and manage the risks that floods pose to human health, the environment, cultural heritage and economic activity);
- Nitrates Directive (aims to protect water quality across Europe by preventing nitrates from agricultural sources polluting ground and surface waters and by promoting the use of good farming practices) and the Common Agricultural Policy (in terms of environment, aims relating to resource efficiency, soil and water quality and threats to habitats and biodiversity);
- Habitats Directive (on the conservation of natural habitats and of wild fauna and flora) and Biodiversity strategy for 2020 (aiming to halt the loss of biodiversity and ecosystem services in the EU by 2020).
- EU strategy on adaptation to climate change (aiming to make Europe more climate-resilient);

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When looking at LAGOONS recommendations, taking into account the science-policy-stakeholders context in a pan-European perspective, one can see that results will have impact in the implementation of many EU water related policies. More specifically, environmental recommendations from the project participatory processes, aiming for the integrated management of European coastal lagoons ecosystems, can be summarised as follow: i) Sustainable use of water resources; ii) Agriculture based on modern technologies and practices, and diversified agriculture with crops adapted to the local conditions; iii) Maintenance of natural habitats and endemic species and establishment of means and ways of nature conservation to sustain traditional and other uses of lagoons ecosystem; iv) Increase RTD on flood threats, nutrient inputs from the catchment and hydrology; Increase RTD on impact of climate change on water resources and ecological conditions. These can be translated in to the following initiatives concerning management implementation: i) Sustainable use of water resources; ii) Best agricultural practices; iii) Assessment of ecosystem services and their beneficiaries; iv) Spatial planning of activities taking into account natural habitats and enabling the local traditional activities and livelihood's; v) Elaboration of a best practices guide for the natural and human capital balance; vi) RTD on flood risk, adaptation to climate change and eco-hydrology. Finally, these management recommendations are coupled with a set of policy guidelines, from local-regional-national-European setting.

The main target EU policies identified within LAGOONS are:

- Regional – River basin management plans;
- National – Water law (water uses regulation and surveillance); National nature strategies;
- EU level – WFD (chemical and biological indicators); MSFD; Nitrates Directive; CAP – Common Agriculture Policy (2014); EIA – Environmental Impact Assessment; Habitats Directive (Natura 2000); Biodiversity strategy for 2020; Floods Directive; EU strategy on adaptation to climate change

Finally, one practical impact of LAGOONS results was the contribution, within the Common Implementation Framework of the EU Biodiversity Strategy, to the activities of the Working Group on Mapping and Assessment of Ecosystems and their Services (MAES), coordinated by EU/DGEnv and EU/DG JRC. In this context, LAGOONS contributed to the pilot on marine ecosystems, is acknowledged in 2nd MAES report. LAGGONS also supported the Transboundary WebGIS of the Vistula Lagoon and the project is acknowledged in the related publication Kalejdoskop GIS, vol. 3.

Maes J., et al. (2014). Mapping and Assessment of Ecosystem and their Services. Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 20202. Publications office of the European Union, Luxembourg. ISBN 978-92-79-36161-6. doi: 10.2779/75203.

Szymanek L., Szura P. Margonski P. (2014) Transboundary WebGIS of the Vistula Lagoon, pp 10-11, [In:] Kalejdoskop GIS, vol. 3, ESRI Polska Sp.z o.o., Warszawa, 123 p. (in Polish)

1.4.4 Modelling

There is a wide range of models, and all of them have some advantages and limitations, which are usually difficult to assess for others than the modelling experts. The demonstration of results of the

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applied models in the LAGOONS project for the stakeholders in the set of three stakeholders workshops have resulted in both an acceptance of what models can be used for and its limitation. So the modelling impact can be regarded as awareness rising. Another impact is that the targeted approach by the LAGOONS scientist to explain the complex modelling results in an easy available form was well taken by the stakeholders. To that end, we believe that the LAGOONS approach to use models to determine the impact on various scenarios was an impact that could be applicable also in similar projects.

Impacts of climate change and socio-economic scenarios

In total, the climate impact assessment for three future periods 2011-2040, 2041-2070, and 2071-2098, and the assessment of socio-economic and combined scenarios for the period 2011-2040 provide useful insights into possible future developments in the four drainage areas of the lagoons, defining important inputs for the lagoons themselves. The results of these impact studies can be used for the development of adaptation measures to climate change, and for planning changes in land use and water management. Below the recommendations from the project in this respect are shortly described for the four case study areas.

RIA de AVEIRO - The main conclusion from the impact assessment for the Ria de Aveiro is that water managers, stakeholders and population have to be ready to decreased water availability in the future due to warmer climate. Therefore, the focus of adaptation measures should be in this direction, whereas water quality should not be a large problem if land use and current water management do not change drastically.

MAR MENOR - The main message for water managers and stakeholders is the same as in the Ria de Aveiro case: adaptation measures should focus mainly on water saving technologies. Water resources, which are scarce already now, and almost fully dependent on water transfer from another catchment (Tagus-Segura inter-basin transfer), may become even more scarce in future. Besides, measures related to reduction of point source pollution and diffuse nutrient pollution from arable land should stay in focus of managers and stakeholders. Though the simulated average impacts do not show notably increasing nutrient loads, they reflect only long-term average dynamics, and hydrological extreme events in future may have negative consequences on water quality characteristics.

TYLIGULSKYI LIMAN - The catchment of the Tyligulskyi Liman has a strong vulnerability to land use and management changes. The impacts of socio-economic and environmental changes on water quantity and quality are quite significant, as this area and its discharge regime are strongly influenced by human activities (filling of irrigation ponds). The sensitivity is higher for water quality than for water quantity outputs. However, the impacts of potential climate change as projected by the "best fitting" scenario for this catchment are high, and lead to a strong decrease in both, water inflow and nutrient loads. These results are associated with a quite high uncertainty resulting from the high diversity of climate change projections in this catchment (due to its location close to the border of the

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covered European area). In general, freshwater inflow to the lagoon is a problem in this region, and further analysis of water management options together with climate change impacts would be beneficial. For that, more consistent and reliable climate scenarios would be desirable for this region in order to reduce uncertainty of projections.

VISTULA - The simulation results show that the catchment of the Vistula Lagoon is influenced by both expected change in climate as well as socio-economic changes. Though expected changes in climate can be seen as beneficial for this region, one should not forget about water-related extreme events like floods and droughts, which were not investigated in this study. Therefore, adaptation to climate change is still needed, and measures related to water availability, flood protection, improved sewage treatment and better management practices in agriculture are still important, and should be considered for this region. Changes in land use and agricultural practices can have significant effects on water quantity and quality, and every measure should be well debated before its implementation. Although some changes in cropland and forest areas assumed in scenarios may be not realistic, they help to understand the system and processes in the catchment better in order to derive reasonable adaptation measures.

The results produced on the assessment of climate change impacts and socio-economic scenarios for water quantity and water quality could potentially support stakeholders, water managers and population in the study areas. They could be:

- Helpful for planning of adaptation measures to climate change for freshwater availability and water quality issues,
- Useful for planning changes in water management (e.g. WWTP in Kaliningrad, ponds in the Tyligulskyi, irrigation in Mar Menor),
- Helpful for stakeholders and managers to define the possible directions of change in nutrient loads and to design more effective plans in order to reduce nutrient inputs,
- Can support implementation of environmental policies (mainly the Water Framework Directive, the Urban Water Directive, the Nitrates Directive and the HELCOM Baltic Sea Action Plan).

The obtained results have already been used to inform stakeholders in the case study areas eg at the stakeholder workshops. In addition, stakeholders and water managers in the CS lagoons have also been informed via the project web page and the webGIS platform, where, respectively, the project reports and briefs, and pdf-maps are available for download. It is planned to disseminate the project results also after completion of the project on occasions when the environmental situation and future investments in the areas are discussed with stakeholders and managers.

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1.5 The address of the project public website

The LAGOONS website has been developed, following the references for the structure/ layout of "EU Project Websites - Best Pratice Guidelines", as well as some benchmarking to other FP7 funded projects websites. It has been installed at the servers in the University of Aveiro and it was adopted the tool Wordpress (blog and website editor), so as to ease administration and updates of information in a regular way. A simple and traditional layout (banner + menu+ bodytext) has been used, giving priority to a user-friendly and direct display of information (more detailed information cab be found in *Deliverable D.1.3* available at LAGOONS webpage)

The address of the project public website is: http://lagoons.web.ua.pt/

2 Dissemination activities and exploitation of results

The LAGOONS partners have been fully committed to ensure the maximum possible exploitation of the project results, caring out successfully dissemination and exploitation activities, which included involvement in keeping the webpage updated, conferences, seminars, workshop, media, among others.

Dissemination work begun at an early stage of LAGOONS project by building the project hallmarks:
i) The logo, representing a coastal lagoon and the dynamics of water from catchment to coast;
ii) A fact-sheet presenting the project (in English);
iii) Three thematic fact-sheets for each case study lagoon - Case study area description and end users; Spatial Planning and Governance; Socio-economic and policies issues (in English);
iv) The website, through which general information on LAGOONS is made available, played a major role in the dissemination of the project activities and results. At LAGOONS webpage (http://lagoons.web.ua.pt) all public results of the project are made available, which includes the majority of scientific publications, all public deliverables, factsheets, reports (mostly in English), technical briefs in each case study local language (Portuguese, Polish, Russian, Ukrainian and Spanish); consortium activities, links and collaborations with other research projects, photo gallery, videos, project agenda, etc.

International publications, local language reports & a hard cover Book (IWA publishing) played an important role in the dissemination of LAGOONS results. Several peer-reviewed and conference papers were already published, a few are now submitted, and several more papers are in preparation and expected to follow in the next months. At least 4 technical briefs in local language were produced per CS lagoon and are available at LAGOONS web page. Local language reports addressing the management recommendations from the participatory processes involving each case study stakeholders were also produced (for a summary Multilanguage report about recommendations from each case study lagoon see *Deliverable 7.1*):

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LAGOONS (2014) Gestão integrada de lagunas costeiras europeias no contexto das alterações climáticas: A Ria de Aveiro. (*Integrated water resources and coastal zone management in European lagoons in the context of climate change: The Ria de Aveiro*) [Lillebø AI (Eds.)] 60 pp. (in Portuguese).

Tuchkovenko, Y.S. and Khokhlov, V.N., Eds. (2014) Комплексне управління водними ресурсами та береговою зоною в європейських лагунах за умов зміни клімату (*Integrated water resources and coastal zone management in European lagoons in the context of climate change*). Odessa State Environmental University. Final Report, 171 pp. (in Ukrainian).

Bello C., Loret J. and Marin A. (2014) Escenarios Futuros del Mar Menor. LAGOONS: Informe 8p. (in Spanish and English)

Zaucha Jacek and Matczak Magda, (2013) Program Zarządzania Regionu Zalewu Wiślanego (Program of the Vistula Lagoon region management), Instytut Morski w Gdańsku (Maritime Institute in Gdansk) (in Polish)

A book based on the key results from the project, complemented with invited contributions from the 'sister' project on the EU-FP7 call topic ENV.2011.2.1.1-1, ARCH, is being published by IWA – International Water Association (detailed description of the book can be found in *Deliverable 7.2*, available in the webpage).

Lillebø AI, Stålnacke P, Gooch GD (Editors) (2015) Coastal Lagoons in Europe: Integrated Water Resource Strategies. International Water Association Publishing, UK.

PhD and MSc thesis in the frame of the LAGOONS project: 1 conclude and 7 on-going PhD, and 4 concluded and 3 on-going MSc.

LAGOONS stakeholder's workshops and an international conference organized in the last semester of the project also played an important role in the dissemination of LAGOONS results (for more details on lagoons stakeholders workshops see *Deliverables D4.2 & D7.1*).

The International Conference 'Between the River and the Sea' was held in Dundee, Scotland on September 16-18, 2014 and was hosted by the University of Dundee within the frame of LAGOONS. The conference attracted more than 50 participants (both scientists, decision takers and policy makers) from 10 European countries and Canada, South Africa and Japan.

At the end of the conference the participants agreed on the following statement:

There is a need to create an integrated vision for all European coastal areas and its drainage areas. More specifically there is a need for better coordination of transboundary waters and for a single coordinating unit for coastal zones management. Openness around data and information sharing is also needed in order to include citizens and stakeholders into the management of the lagoons. The science-policy interface should be improved and it is also necessary for better recognition of the connectivity from land, streams, rivers, lagoons and coastal zones.

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LAGOONS actively pursued **cooperation** with European and national entities, working groups, and other research projects. Relevant examples are:

Projects: ARCH, ARTWEI, CONSIDER, ECOSUPPORT BONUS+, KLIMAT, MOMENT, VILA, STAGES, STREAM, EcoWeb, LTER-AVE, ADAPT-MED, ENV-NCP-TOGETHER

Working groups: WFD CIS SPI, NWRM Med, MAES WG

European entities: EU/DGEnv and EU/DG JRC

Broader audiences were also targeted, with two videos: i) http://vimeo.com/106219066 (in English); ii) http://www.bioforsk.no/ikbViewer/page/forside/nyhet?p_document_id=103018 (in Norwegian), and http://www.bioforsk.no/ikbViewer/page/en/article?p_document_id=103154 (in English); one Euronews TV-clip http://www.euronews.com/2013/03/25/lagoons-under-the-microscope/ (in 12 broadcasting languages) ; Two magazine publications (International Innovation); several interviews to the Media (radio, on-line news and news papers). All these dissemination products are available at LAGOONS webpage.

Concerning the **exploitation of results**, LAGOONS falls within the exploitation activity of non-commercial exploitation, which is means that results are available to be further exploited by the project partners and by potential external users.

This regards:

- The LAGOONS webGIS platform;
- The LAGOONS innovative methodology to address the science-policy-stakeholders interface;
- The management recommendations for an integrated management of European coastal lagoons.

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