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Lead authors	Kieran Reilly
Contributors	Sergi Ros (City of Barcelona), Catherine MacManus (MOWI Ireland), Sue Manson (UK Environment Agency), Joaquim Cortes, Javier Romo Garcia (Port of Barcelona), Javier Villa (AVRAMAR), Inger Graves (Xylem)
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Executive summary

This study sets out to assess the economic value of ocean observations in qualitative terms. The study aims to examine the perspective of selected co-developers and end users on the impact of the EuroSea Key Exploitable Results (KERs) on them. While efforts were made to collect quantitative data on the economic impact of the results on the users, this report uses a focussed case study approach to qualitatively assess the value of the demonstration products and services for the co-developers and users. The report focusses on the main demonstration products and services with potential for commercialisation in EuroSea that were identified in the exploitation strategy. These include:

- Oceanographic Services for Ports And Cities (OSPAC) software – real time alert to provide forecast of sea conditions (WP5)
- Solution for marine sensors to measure and forecast oxygen, heat and pH related Extreme Marine Events onsite for aquaculture – monitoring system for extreme marine events at aquaculture sites (WP6)
- Prototype sea level planning and scenario visualisation tool (WP5)

The methodology used was a case study approach using semi-structured interviews with the end users to qualitatively assess the impact of the KERs and ocean observations on them. This report focusses on the qualitative impact of demonstrator outputs.

Key findings and recommendations

The responses to the interview questions show that there is an economic benefit to the users of the demonstrator results and ocean observations in general. The value is derived from the provision of real time data and predictive models that leads to cost savings for the organisations interviewed. Quantifying these benefits in monetary terms in a meaningful way remains a considerable challenge and further case studies on the value of ocean observations are required.

The interviews have shown that the co-development of EuroSea Key Exploitable Results has been successful. This process was key to ensuring that the products and services developed in the project met the requirements of the users. This also helps to maximise the impact and benefit of the outputs for the users. Continued co-development is recommended to help enhance the benefit of ocean observation products for specific end users.

The availability and coverage of data remains a key challenge to maximising the economic impact of ocean observations. Further funding is required to fill gaps in data coverage and availability of local data. Other sources of funding for ocean observations should also be pursued, such as models of co-funding between research organisations and users for the development of specific data products that are useful to them.

1. Introduction

The availability of sustained ocean observation data helps to enhance our understanding of the ocean. They also provide a wide range of societal and economic benefits in relation to safety, operational efficiency and regulation of activities in seas and the ocean (Rayner et al, 2019). The value of the ocean economy in terms of global gross value added activity was estimated by the OECD to be $1.5 trillion USD in 2010 and this is expected to double by 2030 (OECD, 2016). Delivering this growth in economic activity is dependent on ocean observations. This report looks at the role that ocean observations and associated products and services play in supporting the sustainable development of the blue economy.

Key Exploitable Results (KERs) refer to the main results and outputs developed by EuroSea project members. This includes results that have potential for commercialisation and those to be used to inform policy and for further scientific research. This report consists of case studies of a number of the EuroSea KERs to estimate the economic value and impact of them for end users. The main demonstration products and services with potential for commercialisation in EuroSea that were identified in the exploitation strategy include:

- Oceanographic Services for Ports And Cities (OSPAC) software – real time alert to provide forecast of sea conditions (WP5)
- Solution for marine sensors to measure and forecast extreme marine events at aquaculture sites (WP6)
- Prototype sea level planning and scenario visualisation tool (WP5)

For this study, it was decided to focus on three KERs that were most developed at the time the study took place in 2022. The KER on low maintenance tide gauges was not included due to the fact that the gauges had not yet been installed. As the tide gauges have not been installed yet and there were not any co-collaborators to interview it was decided to focus on the three other KERs that had been identified.

The overall aim of the study is to examine the perspective of selected co-developers and end users on the impact of the EuroSea Key Exploitable Results on them. The objectives are to interview the users to gather information on:

- Use, importance and impact of the prototype results
- Future versions of the EuroSea prototype result
- Experience with the process of co-developing the EuroSea prototype
- Use of ocean observations in general

In addition, the paper assesses the potential economic value of the ocean observations based on the KERs and looks at the wider market opportunities.

2. Background and context

Several studies have been carried out to estimate the value of ocean observations. The complexity of estimating the value of ocean observations has been highlighted in many of these studies. In 2018, the OECD conducted an analysis of the socio-economic value of sustained ocean observations (OECD, 2018). This involved a comprehensive review of over 90 papers written on the value of ocean observations to reveal the extent of the current knowledge on the economics of ocean observations. The report outlines that the costs of ocean observing are relatively easy to calculate in comparison to the benefits, which are broad, often poorly defined and are difficult to quantify in monetary terms. As a result, few of the benefits identified have been valued in a meaningful or accurate way with many of the wider benefits difficult to value monetarily. The OECD report categorises the socio-economic benefits associated with sustained ocean observations in three broad areas: direct, indirect and social benefits. Direct economic benefits are generated by the use of commercial products/services developed using ocean observations. Indirect economic benefits are accrued when an end user derives an indirect benefit from the purchase of an information product or service resulting in whole or in part from ocean observations. Societal benefits are received by society in ways that are often easier to identify than to quantify. The different types of benefits of ocean observations can be assessed either qualitatively or quantitatively. In the literature reviewed, two-thirds of the benefits are assessed quantitatively.

According to the OECD, value chains provide a useful tool for identifying the benefits associated with ocean observations (Jolly et al, 2021). Their case study on value chains in public marine data in the UK found that marine data contributes to better knowledge and improved tools that generate various economic and societal benefits. These include revenues from the sale of marine information products and the productivity gains (i.e. cost savings and cost avoidances) derived from them. Other societal benefits highlighted include those related to environmental performance and improved ocean governance in general.

A cost-benefit analysis of the Marine Environmental Data and Information Network (MEDIN) in the UK showed that the benefits of operating the system greatly outweigh the costs, with a benefit to cost ratio (BCR) of 8.2 (EFTEC and ABPmer, 2019). The benefits identified were search time savings, avoidance of duplication of primary marine data gathering, improved formatting and storage processes and improved decision making due to greater availability of marine data. The costs included user time costs involved with the upload of data and metadata and financial costs related to the running of MEDIN. The findings in the study highlight the high value and cost effectiveness of MEDIN.

A similar study of relevance is a cost-benefit analysis (CBA) of the establishment of Joint European Infrastructure network for Coastal Observations (JERICO) as a permanent and formal European Research Infrastructure (RI) (Gaughan et al., 2019). The two options for a permanent RI considered were a European Research Infrastructure Consortium (ERIC) and an Association Internationale Sans But Lucratif (AISBL). The potential benefits for JERICO partners associated with being a member of a permanent RI include data cost savings, public procurement, transnational access (TA) and additional commercial access service revenues. The results show that both options return a surplus of benefits to society with the ERIC option providing a slightly higher surplus of benefits.

Cristini et al. (2016) note that the information needed to quantify the economic benefits of ocean observations is currently lacking. However, the report does provide a breakdown of the Total Economic Value (TEV) for Eulerian observatories. TEV consists of use benefits, that are derived from the direct and indirect use of products or services developed from ocean observations, and non-use benefits. In general, these benefits are derived by improving decision making around marine resource management as a result of improved information from ocean observations.

In 2021, the National Oceanic and Atmospheric Administration (NOAA) created an Ocean Enterprise report on US business activity in ocean measurement, observation and forecasting over the period 2015 to 2020 (NOAA, 2021). The report found that the contribution of ocean-based activities to the overall US economy is currently significant and is growing. The study identified 814 US businesses active in provision of Ocean Enterprise products and services with total employment of 325,000 Full Time Equivalent (FTE) and revenue of US$8 billion. The period covered saw a large growth in the provision of autonomous systems as platforms for ocean observations and measurement. Over the period, the share of technology providers that delivered ocean data platforms, including autonomous underwater and surface vehicles, nearly doubled.

In addition, the US Integrated Ocean Observing System (IOOS) are producing a catalogue outlining the benefits provided by ocean observations. The web-based catalogue will provide a comprehensive and valuable resource outlining a range of societal and economic benefits related to safety, operational efficiency, regulation, and management of activities in the marine environment.

A recent study assessed the extent to which the Australian community receives net benefits from its investment in the Integrated Marine Observing System (IMOS) (Lateral Economics, 2021). For the study, they use the benefit-cost ratio (BCR) as their core metric to estimate the dollar value of benefits received in relation to the dollar value of costs spent. Among others, the expected benefits were thought to include:

- Better management of commercial fisheries
- More accurate weather forecasting
- Natural disaster preparedness including coastal adaptation
- Improved policy responses to environmental challenges
- More accurate forecasting of ocean currents to aid navigation
- Public good value of better knowledge of the ocean

The value of these benefits was estimated to compare with the costs of IMOS for the cost-benefit analysis. The costs included were those which were attributable as Australian Government contributions or partner co-contributions. A 50-year period for the CBA was considered. Economic modelling demonstrated that IMOS yields benefits of many multiples of its costs, with a benefit-cost ratio of 4.7:1. For the Australian Government, the upper bound of the benefit-cost ratio is 12 to 1, though a more conservative estimate is 7.6 to 1.

Bernkopf et al (2022) carried out a study on transforming useful science into usable societally valuable information. This study focusses on the economic value of reduced cost uncertainty and highlights the benefits of Essential Ocean Variable (EOV) data to reduce uncertainty about the state of the ocean. The study outlines that decreased uncertainty leads to more cost-effective decisions by producers and enables targeted policy intervention. The study developed a process for converting an EOV to an ecosystem service and provided an estimate of the value of information as the difference in total costs with and without EOV data.

3. Methodology

As outlined in the Section 2, there is currently no consensus on a methodology for estimating the economic value and benefit of ocean observations. This current report uses a focussed approach to qualitatively assess the value of the demonstration products and services for the co-developers and users. The methodology chosen was a case study approach using semi-structured interviews with the end users to qualitatively assess the impact of the KERs and ocean observations on them. Semi-structured interviews follow a general structure on the main topics to be covered and suggested questions in relation to each topic, which are prepared in advance. This method has a number of advantages over a structured questionnaire, including that it allows the possibility of modifying the line of enquiry, following up on interesting responses and exploring issues and themes in depth. This format enables the interviewer to probe the interviewee on certain areas of interest and allows for flexibility in the line of questioning. The responses can either be written down by the interviewer during the interview or the interview can be recorded and the relevant responses transcribed afterwards. For this study, the interviews were recorded and notes were taken on certain points or interested that arose strongly in the interviews. The list of interview questions is outlined in Annex 1. These questions were adapted for each interview. Five interviews in total were carried out and the main content and findings are outlined in Section 4.

4. Case studies: Value and economic impact of results for end users

This section provides an overview of the KER developed in the demonstration work package followed by the main points that arose from the interview across the four main interview topics outlined in section 1.

4.1. Oceanographic Services for Ports and Cities (OSPAC software) – real time alert to provide forecast of sea conditions

The OSPAC software system consists of an integrated set of tools and measuring instruments that will provide an operational service to the city and the adjacent port in order to minimise risks and improve environmental management. There are two main layers to the system. The first layer includes forecast models of local sea conditions. The second layer is the software that is being developed to provide real-time alerts based on the models. The system will provide an integration layer that will work with existing forecast models for wave, sea level, sea surface temperature and circulation conditions. The software will use the models to deliver real-time alerts by SMS and email to provide forecasts of sea conditions, rip currents, flushing times, floating debris and flood and erosion risk. The use of local models, depending on their availability, will enable the system to be rolled out to other ports. (Figure 1)

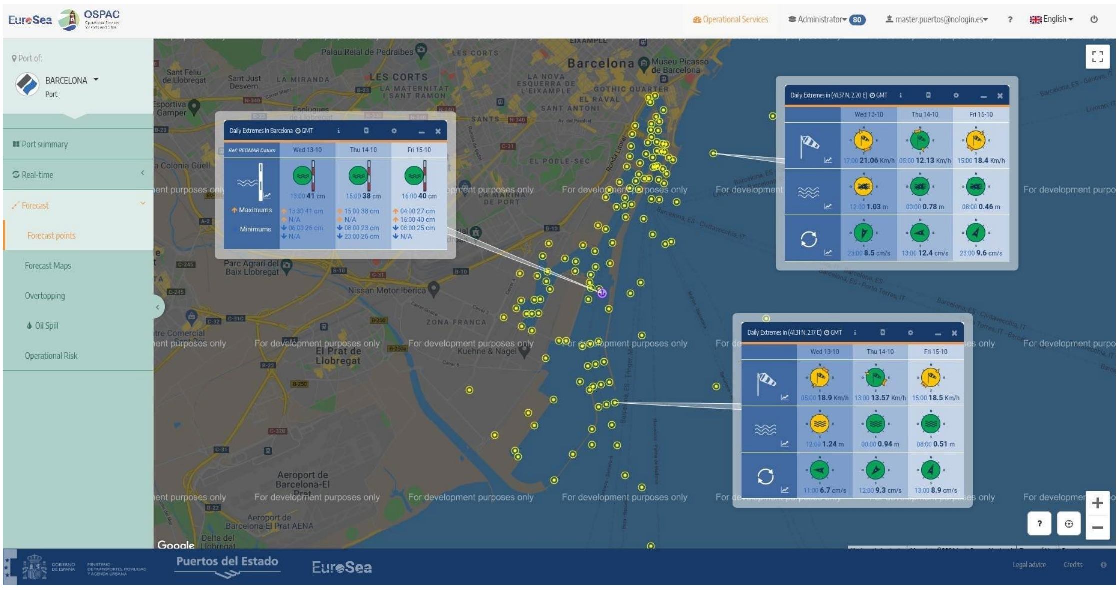

Figure 1. Screenshot of the OSPAC software (desktop version). Forecast points at several points of the Barcelona harbour.

4.1.1 City of Barcelona Interview

An interview with Sergi Ros from the City of Barcelona Council took place online on 7th July 2022. The main points of interest from the interview are summarised in the following sections.

Use, importance and impact of the OSPAC software

For the City of Barcelona, it was noted that the OSPAC software has considerable potential in relation to its use for coastal management of beaches and ports. The ability of OSPAC as an operational tool to provide a real time alert system is seen as a major benefit. The software will be used for a range of purposes including estimating operational days at ports and beaches and for specific projects (e.g. construction of a breakwater structure). OSPAC will help to improve decision making regarding beach closures and movement of vessels if a hazardous marine event were to occur. One of the key benefits of the software is that it is very visual and it will allow for specific studies to be carried out and analysed in a visual manner. It was noted that use of the software will have a positive economic impact in terms of avoiding and reducing costs of damage to beaches, vessels and port infrastructure. The City of Barcelona would recommend use of the OSPAC software to port authorities or other companies that are active in the Barcelona coastal area.

Future versions of the OSPAC software

The next step for future versions of the OSPAC software would be to include additional features to the tool such as incorporating data to the models on wind, waves, salinity, currents, etc. The lack of availability of this data could be an issue to further developing the software. It was noted that it would also be useful to examine other coastal areas in the city of Barcelona.

Experience with the co-development process

The City of Barcelona were very satisfied with the co-development process. Nologin and Puertos del Estado approached the City of Barcelona and they had an initial meeting to determine what their requirements were. The City of Barcelona provide data for the models used in the toll and felt they were able to collaborate effectively with EuroSea partners in developing the tool.

Use of ocean observations in general

In relation to the use of ocean observations in general, the City of Barcelona regularly use this data to inform better decision-making on coastal management. They are aware of the importance of this data in relation to their daily operations. Data is used for a range of purposes including in models to predict storms and other potentially hazardous events, oil spill detection and overtopping in ports. The data informs decisions on coastal management including beach closures and when to move ships to safer areas.

4.1.2 Port of Barcelona Interview

An interview with Joaquim Cortes from the Port of Barcelona took place online on 5th August 2022. The main points of interest from the interview are summarised in the following sections.

Use, importance and impact of the OSPAC software

The OSPAC software has the potential to be used daily by oceanographic and technical operators in the port. The information provided by the platform is needed on a regular basis for port operations. For example, data on waves is very important for navigation purposes in the port and this information is consulted frequently. One of the main benefits of the software is that it gathers a wide range of information needed for efficient port operations in one platform. The ability to access this information in the platform at the same time instead of having to change software is a part of the added value of OSPAC. Wave and wind data often have separate platforms and when there are two windows open simultaneously it can be difficult to follow. In this was OSPAC is more user friendly for operators.

The software is also very useful for dealing with oil spills in the port as it can make simulations on areas that will be impacted by the oil spill. This additional information will help to make better decisions and reduce the environmental and economic impact of these incidents. This will also have a positive economic impact on operations on the port by focussing the response on the areas that are most affected. This will save time and money and allow for the more efficient use of resources to combat the oil spill. The Port of Barcelona would recommend use of the software to other ports in Spain.

Future versions of the OSPAC software

The Port of Barcelona noted that the tool is very useful for viewing a range of information required for successful port operations on one platform. Older data is currently not available on the platform and future versions of the software could allow specialist users to access longer time series data.

Experience with the co-development process

The Port of Barcelona were involved as a demonstration site for the OSPAC software and as an end user of the tool. They provided feedback on the software at various stages of its development. They were very satisfied with their involvement in the programme and the time they dedicated to it. The output justified the additional effort for their input to developing the software.

Use of ocean observations in general

The Port of Barcelona use real time ocean observation data on a regular basis when they are needed. The data are used for preparation and scheduling of works in which ports are involved, such as water sampling and monitoring campaigns and dredging works. Ocean observation data also helps to improve the safety of visitors in public areas against events such as overtopping in the case of bad weather conditions or storms. They also help to determine the origin of polluting discharges and analyse and forecast trajectories of oil spills and debris. The Port of Barcelona also look at forecasted ocean data every day. Data are accessed from the Cuadro de Mando Ambiental (CMA) app on the Puertos del Estado website. The Port of Barcelona collect data form their tide gauges and wave buoys and these data are publically available on the CMA app.

In terms of the economic impact of ocean observations for the operations of the Port of Barcelona, the planning of work during optimal weather conditions means there is more efficiency when performed. The use of this data also helps to avoid cancellations and difficulties on the execution of works. In addition, preventive actions in the case of overtopping events can reduce potential risks and damages to people and moored boats, infrastructures, dock equipment and machinery, etc. The OSPAC software is viewed as having an added value in addition to the existing data already used by the Port of Barcelona.

4.2. Solution for marine sensors to measure and forecast extreme marine events at aquaculture sites (WP6)

This system is an application for marine sensors to measure and forecast extreme marine events at aquaculture sites in the North East Atlantic (Ireland) and Western Mediterranean (Spain) through a setup including optimal sensor, location and measurement cycles for ocean observing. The innovative solution is an increased operational ability connecting in-situ sensors (for oxygen, temperature, turbidity, currents, waves, salinity, pH, ORP and algae; Figure 2) via telemetry to land where data is processed in a user-friendly interface to give an environmental alert. The solution allows for real time management and will help to optimise aquaculture operations. Practical training was provided to set-up, operate, maintain and interpret the data products produced. For the system to measure extreme marine events at aquaculture sites, the modelling component is an important aspect of this KER. The in-situ data provided by the two buoys at the demonstration aquaculture sites operated by Mowi in Ireland and Aquamar in Spain was combined with a number of other ocean observing products (including Earth observation and numerical models). This was set up in a web portal developed by the Marine Institute and CSIC to provide both a historical portal and an operational forecasting and warning system.

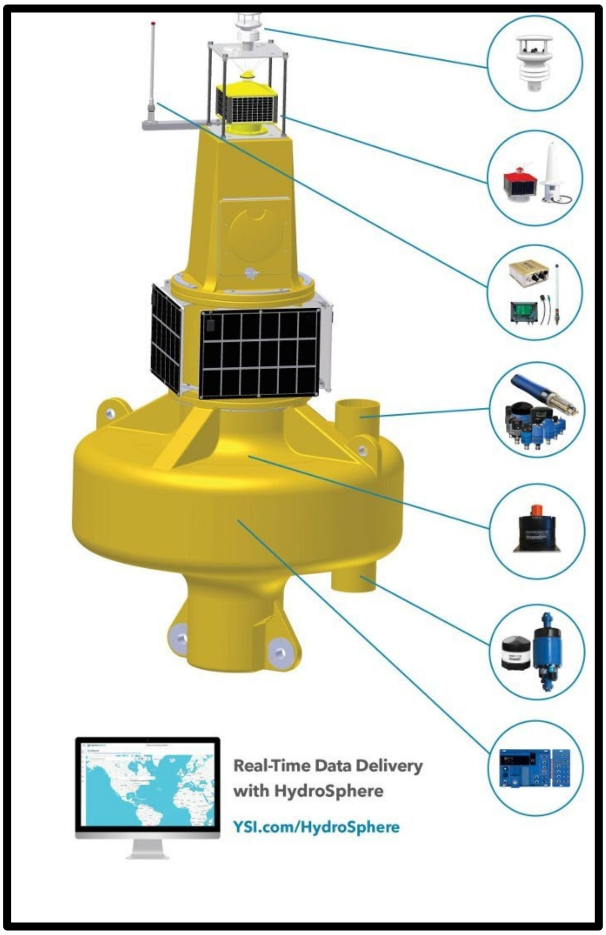

Figure 2. Xylem buoy with suite of sensors4.2.1 MOWI Interview

An online interview with Catherine McManus, technical manager with MOWI Ireland took place on 14th July 2022.

Use, importance and impact of the monitoring system

The buoy was installed at the MOWI Deenish Island aquaculture site in April 2022 and the predictive element of the system was still under development when the interview took place. As such, there was not sufficient time for extensive use of the system. However based on initial use it is expected that the data from the buoy will be very useful for analysing extreme marine events that have occurred, interrogating what contributed to a particular event happening at the fish farm and determining what is the main trigger for certain events. The buoy will also provide up to date data which will be used to model the conditions around Deenish Island.

MOWI Ireland turnover approximately between €80 million and €100 million in stock per year. In terms of the economic impact of the system, it will help to better inform how MOWI operate their Deenish Island fish farm for optimum economic results. The system will help to inform decisions such as the best sites to concentrate fish farming on, length of production cycles, feeding regimes, best time to stock smolts, etc. The environmental data from the buoy will allow MOWI to make optimum decisions on these factors.

Future versions of the monitoring system

MOWI plan to use the data form the buoy and the data products for approximately one year before any further developments are made to it. There is currently ongoing engagement between MOWI, Xylem and the Marine Institute on how to develop the system and data products to meet their needs.

Experience with the co-development process

Overall MOWI were very satisfied with the co-development process and the partners involved. The main benefit of the process for MOWI was further developing relationships and collaborating with the other partners involved, Xylem and the Marine Institute. They also found the approach useful for building up their network for continued collaboration.

Use of ocean observations in general

MOWI collect and use data on ocean variables such as temperature, salinity and oxygen on a daily basis for the operation of their fish farms. They carry out habitual monitoring as part of their environmental requirements, including routine water chemistry monitoring. This data helps to build up a long-term time-series database of environmental monitoring in the areas where they farm. MOWI are willing to make the data they collect at aquaculture sites accessible to the public. In addition to the data they collect, they also use other publically available data.

This data is important for the successful operation of their farms as it helps to inform feeding regimes and to reduce feeding at extreme temperature ends. This helps to reduce feed costs and informs decisions that have a positive economic impact on fish farm operations. MOWI seek improved data information on the environmental parameters they work in at a local aquaculture site scale. This will help to inform if they can farm other species that may have previously been out of the temperature range.

4.2.2 AVRAMAR Interview

An online interview with Javier Cortis, an aquaculture farm manager with AVRAMAR took place on 11th October 2022.

Use, importance and impact of the system to measure extreme marine events at aquaculture sites

The main benefit of the installation of the buoy is that it will give local and real time data on the environmental conditions at the AVRAMAR aquaculture site. The new system will expand on current data to include wave measurements, which is something that most aquaculture farms in Spain do not have. In addition, this local data will be more accurate and will help to support AVRAMAR's production activity. This data is required for successful operations and will support aquaculture farm managers to assess the appropriateness of their work plans. The tool will also help to identify any environmental parameters that may affect production and determine whether activities should be delayed or postponed.

It was noted that it would be very difficult to quantify the economic value of the system at the moment but that this should be evaluated in the future. However, it was mentioned that the main economic benefit will be supporting sustainability plans and the direct impact of the improvement in the efficiency of production. The system will be important to support environmental analysis at the aquaculture sites to help ensure that productivity should be as sustainable as possible with limited environmental impact. The tool will allow aquaculture users to modify standard production style to specific environmental conditions. If the system proves to be successful then AVRAMAR would use it at other sites. In this way smaller producers would also benefit by using the data.

Future versions of the system to measure extreme marine events at aquaculture sites

It was noted again that more time should be given to assess the system as it currently stands but more sensors could potentially be added to the buoy. The next step for the system would be to provide predictions of environmental conditions at the aquaculture site using the data provided by the buoy to validate the models. The predictive element of the system will be very useful for production activity and for programming work at the aquaculture site in advance.

Experience with the co-development process

There was positive feedback on the co-development process and it was noted that there was a good collaboration between the partners. The process was quite straightforward and easy for AVRAMAR as a validator of the system and there were no problems or difficulties encountered. The main benefit of co-development for AVRAMAR is that the system addresses their specific requirements. They also provided the equipment providers data of the local environment that was used for the optimal development of the system.

Use of ocean observations in general

Ocean data is used daily for the operations of AVRAMAR at their aquaculture sites. Historical data is also important for their work to monitor trends and the impact of marine events on the welfare of fish. This data is used to help determine if there are other factors affecting the stress of the fish. The ocean data is used to give a reference on how to programme production activities and to support and inform sustainability plans.

4.3. Prototype sea level planning and scenario visualisation tool (WP5)

This prototype provides a full picture of the scientific predictions and associated uncertainty within the economic decision making framework. The prototype visualises the economic damage resulting from a large set of sea level rise (SLR) flood risk scenarios, accounting for the flood mechanisms at the coastal boundary (Figure 3). The prototype aims to develop a new streamlined approach to modelling the interactions between sea level hazards, economic activity and risk, bringing more science through the risk assessment process, resulting in better informed decision making and investment planning.

In order to develop the prototype, Hull, on the east coast of the UK, was selected as a case study location. The basic premise of the prototype is to visualise the economic damage resulting from a large set of SLR flood risk scenarios. This requires a correspondingly large set of simulations to generate the flood risk data and, potentially, a prohibitive amount of computational expense to estimate the associated economic losses. With the aim of providing a full representation of the scientific uncertainty in the predicted damage, the aim was to reduce the detail in the engineering calculations, which translate the environmental conditions into building level flood impacts, and also the economic calculations that turn flood impacts into damage estimates. This was the alternative to reducing the number of SLR scenarios to be visualised.

Alongside the development of the modelling approach, a visualisation prototype was designed and built to receive, process and visualise the modelling outputs. The modelling method results in a very complex set of data focussed on a wide range of “scenarios”. This visualisation prototype is a web-based interface to the data, allowing the user to easily select a scenario and, importantly, rapidly change the scenario and compare to other scenarios. In this way the user can immerse themselves in the data and get a feel for how decisions on the originating uncertainty levels alter the overall flooding in the region, its distribution and the resulting economic impact.

In its current format, this is a bespoke tool for the city of Hull based on the huge datasets that were available for use. The availability of huge datasets and the computational capability required to generate the visualisations of the economic damage caused by flooding will be a limitation to the further use of the tool. The availability of datasets will determine the sites where the tool can be further developed and used.

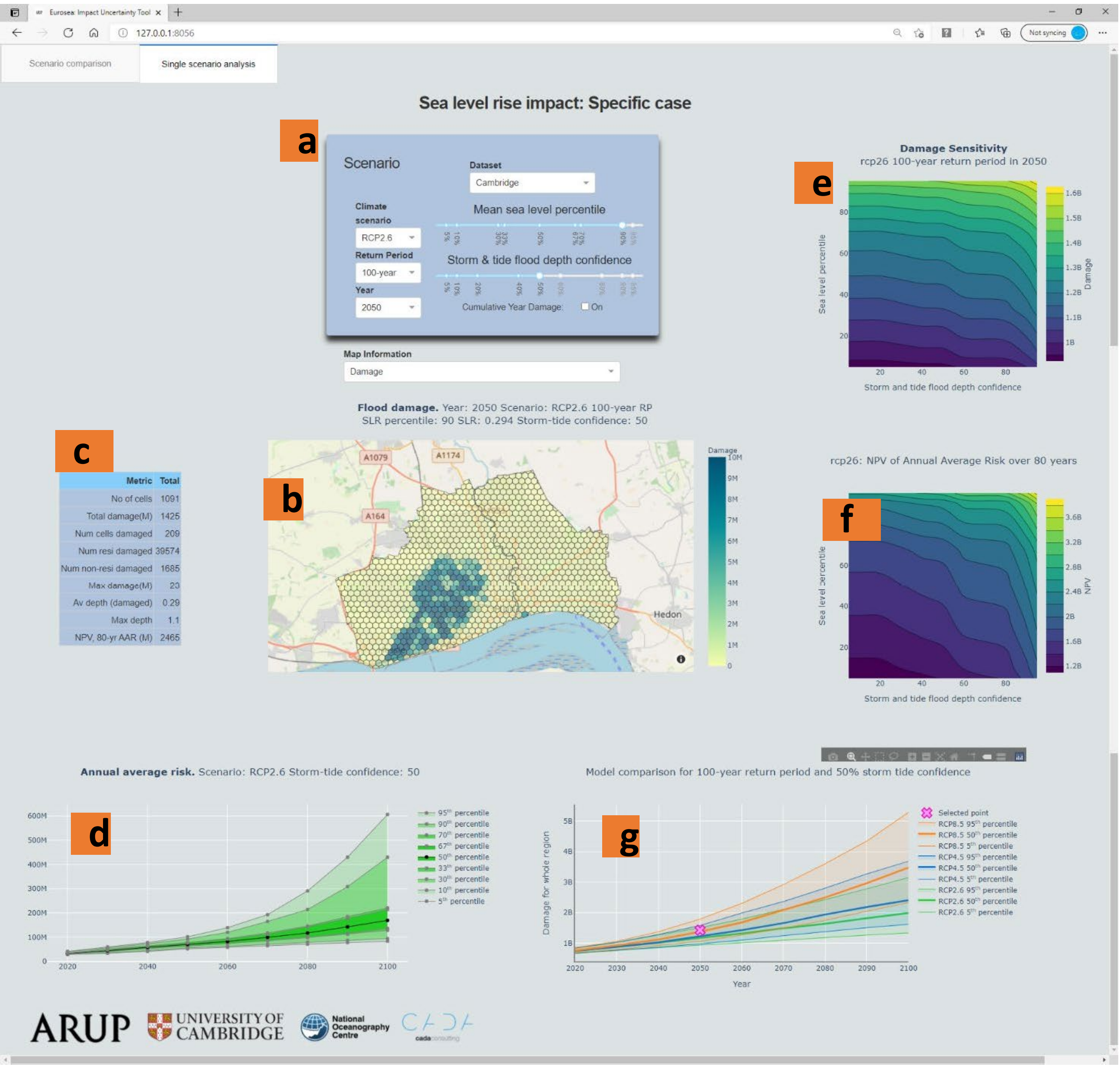

Figure 3. A screenshot of the visualisation prototype for a specific sea level rise scenario

An online interview with Sue Manson from the UK Environment Agency took place on 15th July 2022.

Use, importance and impact of the prototype sea level planning and scenario visualisation tool

The UK Environment Agency (UK EA) intend to use the tool to encourage and help stakeholders to understand adaptive thinking and the importance of timing when making an intervention. The prototype was described as being very powerful as a demonstrative tool to help understand time horizons. It also shows the different economic scenarios in a much more visually engaging and quicker way, which is a key benefit. This speed and ease of use is not always possible with traditional modelling techniques. The tool allows users to quickly see flood risk scenarios and the associated economic damage and enables the identification of areas of potential conflict and areas where there can be compromise. The ability to show users and stakeholders several potential flood risk scenarios and the economic outcomes associated with these while in the same room is seen as hugely beneficial. Another key benefit of the prototype tool is the improved decision-making in relation to flood risk management which could potentially result in cost savings and have a significant economic impact. The UK EA would recommend the use of the tool to other organisations who are grappling with complex issues and where there is a group of stakeholders that all need to understand something clearly at the same time.

Future versions of the prototype sea level planning and scenario visualisation tool

As it stands, the prototype meets a number of the requirements of the UK EA. In relation to future versions of the prototype, more user testing is required to determine what is needed. It was noted that specific users of the tool will likely have different and specific requirements for it.

Experience with the co-development process

The co-development process was described by the UK EA as being very refreshing and enlightening. There was a detailed initial meeting and continuous engagement throughout the process to ensure that the tool was being developed as expected. The involvement of a multidisciplinary stakeholder group at the beginning of the process was highlighted as being very effective in achieving an optimum and successful outcome that may not have happened without the engagement of a wide range of specialists. This approach allowed people from different backgrounds to contribute to the development of the tool and bring a different perspective to how the tool could solve certain problems. The UK EA were very supportive of the type of collaborative approach used by the EuroSea partners.

Use of ocean observations in general

Ocean observation data is fundamental for modelling work in the UK EA and data is used on a daily basis across all the work they are involved in on coastal flood boundaries and flood risk. UK EA use ocean data for forecasting and strategic long term planning and it is fundamental to their understanding of risk. The UK EA collect their own ocean data but also use data from other organisations including the UK Met Office, British Oceanographic Data Centre and Natural Resources Wales. A key challenge recognised by the UK EA is translating the excellent scientific work so that there is better public understanding of its importance. It would be useful to share experience and learnings on how this can be done successfully among other organisations in Europe, rather than tackling this problem separately.

5. Potential Economic Value of Ocean Observations

5.1. Oceanographic Services for Ports and Cities (OSPAC) software

For the OSPAC software, one of potential benefits identified for the Port of Barcelona would be the more efficient use of time and money resources to combat oil spills. A follow up email was sent to the interviewee from the Port of Barcelona asking them to provide information on the cost of the activities such as oil spill response that would benefit from the use of the OSPAC software. From the period of January 2022 to October 2022, the cost of responding to eight oil spills in the Port of Barcelona was approximately €50,000, based on the figure provided. This provides an indication of the economic value of the OSPAC software for the Port of Barcelona in relation to cost savings due to the ability to track oil spills and the reduced response time.

5.2. Solution for marine sensors to measure extreme marine events at aquaculture sites

For the system to measure extreme marine events at aquaculture sites, one of the potential benefits of the system is that it will improve decision-making in relation to production activities, including feeding regimes. A follow up email was sent to the fish farm operators at the Irish and Spanish sites asking them to provide financial data on the cost of feeding and other operating costs at the site in order to estimate the potential economic impact of the buoy monitoring system. While they did not provide any figures for the costs of feeding at the sites, it was noted that feed makes up approximately 47% of the total production costs for Mowi in Ireland and in the Mediterranean feed costs range from 50-60% of total costs. Given the large percentage of overall production costs dedicated to feeding, there is likely to be considerable economic value for the users of system.

Another benefit of the buoy deployed at the Spanish aquaculture site is that the data provided can help with production performance in relation to sea current information and developing a sea working plan to avoid interruptions due to high currents.

Additionally, in January 2020, Storm Gloria led to high winds and heavy rainfall on Spain's Mediterranean coast where sea levels rose over 80cm and record-breaking waves were recorded (Watson, Farley and Williams, 2023). It was estimated that Spanish aquaculture firms lost nearly half of their production as a result of Storm Gloria. A large number of aquaculture suffered net breakages or lost their anchors resulting in a huge loss of fish. Losses to tuna stocks were estimated to be approximately €900,000.

The value of the forecast data is useful to Xylem as they do not currently have the capability of forecasting future ocean states. They are interested in investing in forecasting services developed that use the data collected from the Xylem buoy to train for Machine Learning.

5.3. Prototype sea level planning and visualisation tool

In relation to the prototype sea level planning and visualisation tool, several studies have been done to assess and estimate the economic cost of flooding damage in the UK. Exceptional rainfall in June and July 2007 in parts of England, especially in South and East Yorkshire, Worcestershire, Gloucestershire and Oxfordshire led to flooding which affected many individuals, homes and businesses. A study by the UK Environment Agency under the Flood and Coastal Erosion Risk Management Research and Development Programme quantified the economic cost of the floods to be between £2.5 and 3.8 billion, with a best estimate of £3.2 billion (Environment Agency, 2010). A further study quantified the damages caused by flooding due to heavy and prolonged rainfall in England and Wales between December 2013 and March 2014 (Environment Agency, 2017). The study estimated total economic damages of between £1billion and £1.5 billion, with a best estimate of £1.3billion. Residential properties suffered the greatest proportion of flood damages, with 25% of total damages occurring to this sector (best estimate of £320 million incurred by 10,465 properties).Flooding in England in the winter of 2015 to 2016 was estimated to cost the economy £1.6 billion. The economic losses from flooding between November 2019 and March 2020 were estimated to be about £333 million, although without adequate flood defences this could have been as much as £2.1 billion (Environment Agency, 2021). In relation to the Humber region specifically, the region experienced its worst tidal surge on record in 2013 and the impact of flooding in the area was estimated to be £90 million with the sum total of all damages to people, property, business and the environment expected to be much higher. It was estimated that a significant flooding event in the area could results in direct damage costs of £12.5 billion, consequential damage of £10.8 billion and potential lost investment to the region of £8.8 billion lost to the region. The values provided in these reports provide a good indication into the potential economic value of the planning tool in terms of the cost of damage avoided.

6. Wider Market Opportunities and Costs

6.1. Oceanographic Services for Ports and Cities (OSPAC) software

In relation to the wider market opportunities for the OSPAC software, it is intended that the use of the software will be extended to other ports in Spain after the EuroSea project. The use of the software will initially depend on the availability of forecast models for respective ports. According the EU Blue Economy report 2022, port activities is a mature and growing Blue Economy sector. A market analysis of the ports in Spain shows that ports play a key role in Spain's external trade, handling 60% of exports and 85% of imports. The largest port in Spain is Valencia port with gross value added of €2.4 billion. Two of the largest ports in the world are located in Europe. EU ports enabled maritime transport to handle 77% of the EU's external trade and 35% of all intra-EU trade. The top five EU ports in terms of cargo capacity are Rotterdam (Netherlands), Antwerp (Belgium), Hamburg (Germany), Valencia (Spain) and Piraeus (Greece). The value added generated by port activities in Europe was €27.9 billion in 2019, with gross profit of €11.8 billion and turnover of €68.5 billion.

Further funding is needed to fully deliver the KERs. For the OSPAC software, the costs associated with further development will depend on the availability of existing forecasting models. This will include the costs of developing the software and the personnel required to deliver this and the costs to maintain the software once it becomes operational.

6.2. Solution for marine sensors to measure extreme marine events at aquaculture sites

In relation to further expansion of the system to measure extreme marine events at aquaculture sites, the intention is to initially expand the system to other aquaculture farms operated by MOWI in Ireland and Aquamar in Spain. The sites chosen will be determined by the availability of ocean models for these areas. The Irish Seafood Development Agency, Bord Iascaigh Mhara provides an annual report on the Irish aquaculture industry (BIM, 2022). The most recent report provides an economic analysis of the performance of the sector for 2021. The output value in 2021 was €179.8 million with the number of businesses in the sector remaining stable at 266 operating 313 production units. Profitability in the sector was significantly impacted by increasing costs, in particular for stock input and feed costs. Gross Value Added was €87 million in 2021 and net profitability for the sector was estimated to be €800,000.

According to Apromar, the Business Association for Aquaculture in Spain, the national aquaculture harvest in 2020 totalled 307,168 tonnes with an output value of €510.9m. There were 5,262 active aquaculture facilities across the country in 2019.

The majority of aquaculture producers in Europe are SMEs. The total number of aquaculture companies in the EU is estimated to be 15,000. According to the Blue Economy 2022 report, EU aquaculture production is mainly concentrated in four countries: Spain (27 %), France (18 %), Italy (12 %), and Greece (11 %), making up 69 % of the sales weight. These four countries are responsible for 62 % of the turnover in the EU-27.

6.3. Prototype sea level planning and visualisation tool

For the prototype sea level planning and visualisation tool, the availability of the huge flood risk datasets and the computational requirements will determine how and where the tool can be used further. Wider market opportunities beyond the UK Environment Agency would include the insurance industry. The costs of further development will depend on the availability of data for the modelling of the flood and economic impacts. The computational requirements of the tool will be a significant part of the costs.

7. Conclusion and recommendations

This section provides an overview of the main conclusions and recommendations of the case studies interviews on the economic benefit of the selected outputs from the EuroSea demonstration work packages. The main findings and lessons learned from the case study interviews are summarised below.

From the interviews, it is clear that there are economic benefits to the users of the demonstrator results and ocean observations in general. In relation to the demonstrator KERs the main value lies in the availability of real time data to validate the predictive modelling that helps to improve decision making and enhance efficiency in operations. Quantifying these benefits in monetary terms in a meaningful way remains a considerable challenge. Further case studies on the value of ocean observations are recommended to better determine the value of specific applications of ocean observations. Tracking end users and monitoring what the data is used for will also be important step for the economic valuation of ocean observations.

There was an overall high level of satisfaction among all of those interviewed with the co-development approach used by the EuroSea partners in the demonstration work packages. This process helps to ensure that the products and services developed meet the needs of users and maximises the use of project results. This in turn enhances the impact and value of the project outputs for users. For this to be successful early and continuous engagement with user co-developers is key. This has been evident in the EuroSea project and was a common theme across all interviews. Continued co-development is recommended to help enhance the benefit of ocean observation products for specific end users.

The availability and coverage of data remains a key challenge to maximising the economic impact of ocean observations. Further funding is required to fill gaps in data coverage and availability of local data. It is recommended to assess other sources of funding for ocean observations, such as models of co-funding between research organisations and users for the development of specific data products that are useful to them.

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Annex 1: Semi-structured interviews

Introduction and aim of study

The overall aim of the study is to examine the perspective of selected end users and co-developers on the impact of Key Exploitable Results from EuroSea on them. The objectives are to interview the users to gather information on:

- Use, importance and impact of the prototype results
- Future versions of the EuroSea prototype result
- Experience with the process of co-developing the EuroSea prototype
- Use of ocean observations in general

The information you provide will be used in the EuroSea deliverable report on the economic value of ocean observations. The first part of the interview will be in relation to the EuroSea prototype and the second section will refer to ocean observations in general.

1. Use, importance and impact of the EuroSea prototype result

a) Do you use the EuroSea prototype? If yes, what prototype do you use? (OSPAC software, system for measuring extreme marine events at aquaculture sites, prototype for sea level rise planning tool)?

b) How often do you use the EuroSea prototype? How likely are you to continue using the EuroSea prototype? What frequency are you likely to use the prototype?

c) Does the EuroSea prototype meet your specific needs and requirements? Please describe – how does it meet your requirements?

d) What are some of the benefits of the EuroSea prototype for your work?

e) Do your operations rely on the EuroSea prototype?

f) Can you please describe what you think is or will be the economic impact of the EuroSea prototype specifically for your operations? How does this follow on to broader societal impact/benefits? What do you see as some of the broader societal and economic benefits of the EuroSea prototype?

g) In your opinion, how would it impact your operations if the EuroSea prototype were no longer available to you?

h) Do you think others in your sector would use the EuroSea prototype? Are you likely to recommend it to others in your sector?

2. Future versions of the EuroSea prototype result

a) How satisfied are you with the accuracy/performance of the EuroSea prototype? Please describe.

b) In using the prototype have you identified any areas in which it could be improved?

c) How could further versions of the EuroSea prototype be improved over the next number of years to benefit your operations?

3. Experience with the process of co-developing the EuroSea prototype

a) Were you involved in the co-development of the EuroSea prototype? If yes,

b) Were you satisfied with your experience with the co-development process?

c) Could you suggest anything that may have improved the co-development process/experience?
d) What do you see as the main benefit of the co-development process?

4. Use of ocean observations in general

a) How often do you use ocean observation data (for example: tide gauge data, data buoys, etc)?
b) Where do you access ocean observation data? (Eg, data aggregators, data portals, etc)
c) Does your organisation collect any ocean observation data? If so, do you know if your organisation publishes this data anywhere or makes it publically accessible? If so, where?
d) What are some of the benefits of ocean observation data for your work? How do you use ocean data for your work? How does it help your work? (Operational)
e) Can you please describe the economic impact of ocean observations for your operations?
f) Can you suggest any improvements to the ocean observing system in Europe as it currently stands? Do current ocean observation data meet your needs and requirements? What gaps have you noticed?

5. Concluding questions

a) Do you have anything further to add on your experience with the EuroSea prototype result that has not already been covered in the interview?
b) Do you have any general feedback, comments or advice on the interview and how it went?

Closing comments

Thanks again for your help and co-operation and for giving up your time for this interview – it is greatly appreciated. Any output from the interview will be made available to you if you so wish. If you have any further comments or feedback, or if there is anything that you think about at a later time that you would like to add then please contact me.

Probes – Anything more? Could you go over that again? What is your personal view on this? Could you expand on that please? Can you provide an example of that? Can you elaborate please?