Case study report

“The management and prevention of risks affecting the quality of coastal waters associated with aquaculture. A case study of Rias Baixas: the application of GIS analysis”

Carried out in Vigo, Galicia (Spain) by CETMAR

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Section 1: The management and prevention of risks affecting the quality of coastal waters associated with aquaculture. A case study of Rias Baixas: the application of GIS analysis.

1.1. Introduction: justification and objective of study

The selection of suitable sites for aquaculture facilities in coastal waters is a crucial factor in determining the success, sustainability or weakness of marine cultivation (Kutty, 1987). However, the selection of areas to be used for marine cultivation does not only depend on the physical features of the environment but also on a series of key factors that must be taken into account (legal considerations, climatic factors, the features of the coastal environment, types of cultivation, socio-economic factors, coastal activities and use, etc.).

The objective of this study is to demonstrate the usefulness of analyses based on Geographic Information Systems (GIS) in assessing the suitability of aquaculture sites and to indicate their enormous potential as a support tool for coastal management. The study was carried out in the Ria de Vigo estuary, the most southerly of the Rias Baixas estuaries, taking socio-economic factors into account and, in particular, the effect of the overlapping of activities and uses of the coastal zone. In addition, factors relating to the type of coastal environment in which cultivation takes place, the characteristics of the environment and, in particular, the parameters relating to the quality of the coastal waters were also taken into consideration. A tool based on multi-criteria evaluation and GIS analysis was developed to achieve this objective.

1.2. The study area

The Ria de Vigo, the most southerly of the group of Rias Baixas estuaries, has a N45ºE orientation along its main axis and is funnel-shaped. It occupies an area of 175 km², its main axis being 33 km long and the external part of the estuary mouth 10 km wide (Figure 1). It has an indented coastline with many bays and coves (Vilas et al., 1995).

In terms of both the richness of its natural (landscape, wildlife and ecological) features and its cultural heritage, the Ria de Vigo may be considered an unusual enclave whose resources have been exploited since early times. Fishing, shellfish harvesting and aquaculture activities take place on the shoreline of the Ria and are of major socio-economic importance, reflecting a strong cultural tradition. In the coastal waters of the Ria there are currently 13 cultivation polygons divided into squares and containing 478 floating platforms. The main species cultivated on the platforms is mussels (*Mytilus galloprovincialis*), both to obtain “seed” mussels...
and to grow the adult organisms. Other species of shellfish are also cultivated, such as the flat oyster (*Ostrea edulis*), clam (*Ruditapes decussatus*) and scallop (*Aequipecten opercularis*).

Parallel to these uses of the shore, in the coastal area of the estuary there are also 8 municipalities with a population of 400,000 (Guerra et al., 2008) in which significant agricultural and industrial activities take place. The high level of maritime traffic, the shipping, canning and frozen food industries, and activities associated with tourism and leisure, all of which make use of the coastal zone, have led to an overlapping of activities, making coastal management more complex.

![Figure 1. Map showing the location of the study area: Ria de Vigo.](image)

### 1.3. Methodology

The methodology for the study was divided into several phases. First, the georeferenced geographical information available for the Ria de Vigo was complied, focusing on the description of the estuary environment (seabed types, currents, protected zones, etc.), and the economic activities taking place on the coast and in coastal waters. On the basis of the information obtained, the variables of greatest interest to the study of overlapping uses of the coast were selected (Figure 2), namely: waste (both urban and industrial, representing the significance of the concentration of urban and industrial nuclei in the Ria de Vigo), distance from ports (both commercial and recreational), distance from beaches (in terms of the impact of...
floating populations and the presence of a larger number of recreational vessels), distance from (commercial and passenger) maritime transport routes and intensity of surface maritime currents (bearing in mind their significance in terms of the dispersal of possible contaminants). Two environmental variables were included in a second analysis: temperature and salinity of the surface coastal waters (0-5 m).

Figure 2. Variables selected for the study.

As the variables contained specific scales and variation ranges, each one was standardised to obtain a value of 0-1 in each case. On the basis of the values obtained, the raster surfaces were then calculated for each variable. To this end, the marine surface of the Ria was divided into a grid composed of cells whose sides each measured 100 metres, and the value for each variable in each cell was calculated. Two spatial techniques were used according to the parameter being assessed: spatial interpolation using a deterministic technique known as spline, and calculation of values in terms of the Euclidian distance between given variables. The results were incorporated into a polynomial algorithm to which the specific weightings for each of the variables were attributed.

The Analytic Hierarchy Process (AHP) proposed by Saaty in 1980 was used to calculate the relative weightings attributed to each variable. This procedure involves establishing a matrix of pairs of variables that enables the importance of each one to be compared in relation to the
others, thus determining the relative weighting and also estimating a quantitative measurement for the consistency of value judgements for pairs of variables.

1.4. Results

The linear combination of variables multiplied by their weightings resulted in a suitability value for each cell into which the marine surface of the Ria had been divided, thus providing a continuous surface representing variations in the suitability of sites for aquaculture facilities. The relative importance attributed to each variable depends on the judgement of the manager of the coastal zone in question and specific results are obtained for the suitability map according to the weightings attributed (see the example in Figure 3). The resulting suitability map is therefore an interactive tool which the manager may use to assess the importance they wish to attribute to the variables and socio-economic uses of the coastal area and to calculate the impact this would have on the suitability of the actual location of cultivation polygons.

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Figure 3. Example of a suitability map (most suitable areas in green) calculated on the basis of the vector of the weightings shown in the table above the map. In this case, greater importance was attributed to the "effluents" variable.

1.4.1. Integration of environmental variables

In addition to calculating suitability in terms of overlapping uses of the coastal area, two environmental variables were included in the model: salinity and temperature. The predicted surfaces for each variable were obtained on a seasonal basis (for spring, summer, autumn and
winter) by interpolation of the values for the surface water temperature (at 0 to 5 metres) taken from a 3-year set of figures (Pazos et al., 2006; Doval González et al. 2007; Moroño Mariño et al. 2008) published by the Instituto de Control do Medio Mariño – INTECMAR. Taking the resulting values into account and integrating the temperature and salinity variables into the model, a suitability map can be calculated for particular species that are of interest to the study, bearing in mind the optimum temperature and salinity ranges required for cultivation.

1.5. Conclusions

Hierarchical analysis based on a Geographic Information System enabled the suitability of particular species for cultivation in the coastal waters of the Ria de Vigo to be calculated, taking into account the overlapping uses of the coastal area and considering two variables indicative of water quality, namely salinity and temperature. The resulting suitability map serves as an interactive tool that can be used by the manager of the coastal zone to assess the importance they wish to ascribe to the variables and socio-economic uses of the coastal area. The model obtained is a dynamic tool that enables entry variables to be introduced or eliminated and suitability to be calculated on the basis of data of interest to the study of a particular species, type of cultivation or aquaculture area.

This interactive tool is available on the Internet at http:// ancorim.xeogalicia.net.

1.6. Acknowledgements

The study was carried out within the framework of the ANCORIM project, co-financed by the European Union Atlantic Area Programme. We would like to thank INTECMAR for its collaboration and for the data provided as part of the initial information gathering phase of the project and Jose Manuel Parada Encisa for his contribution to the approach to the work and the processing of the geographical information.

1.7. Bibliography


Section 2: Transferability of the tool to other coastal regions

The sustainable development of aquaculture activities depends to a large extent on the selection of suitable sites for cultivation (GESAMP 1996). The high demand and competition for space in coastal zones, together with the overlapping of multiple types of socio-economic activities based on the coast, has led to the need for a detailed study to ensure the sustainability of aquaculture facilities. The study should aim to meet the needs of the sector in terms of infrastructures, materials, and transport and marketing, in addition to identifying the most suitable sites from the point of view of the physical environment, bearing in mind the potential impact on the environment, and the impact to which they are subjected as a result of other coastal activities. Coastal aquaculture should therefore be developed in accordance with an Integrated Coastal Zone Management (ICZM) scheme, since the aquaculture plans or regulations should include a system to determine site suitability (GESAMP 1991, 1996). Such a system should take economic, social and environmental factors into account to ensure that aquaculture systems have the greatest possible chance of success.

The case study which concerns us here focuses on identifying the most suitable sites for the location of floating cultivation platforms in the estuary waters, bearing in mind the possible impact of other coastal economic activities. The most significant activities in the study area were considered, and were each quantified and assessed in terms of their relative importance.

The methodology proposed for this case study can be transferred to other study areas in coastal regions where there is competition for space and the most suitable areas need to be identified in order to reduce the impact caused by overlapping activities. In order to implement the tool in other regions, it will be necessary to review and identify the socio-economic activities taking place on the coast, and to compile the required geographical information. Given the variety of units and measurement scales for each variable, a multi-criteria decision-making analysis requires the values to be converted into comparable scales and units. Each variable must be standardised and a variation range between zero and one must be established for the values. Finally, the preferences of decision-makers are incorporated into the model, and each variable is attributed a weighting or relative importance in relation to the others, which will vary in each study area according to the variables under consideration and their importance on a regional level. The weighting of each variable is calculated on the basis of the importance attributed to it and will be a subjective value in accordance with the criteria used by coastal managers and decision-makers. The value of the weighting is calculated using the comparison of pairs method developed by Saaty (1994). The values under consideration and the relative importance of each are combined using a multi-criteria evaluation (MCE) based on the hierarchical or weighted combination of the sum of the individual weightings of the variables (see the explanation of the methodology in Section 1 of the report for further details).
The tool may be of use to coastal authorities or managers who have to carry out spatial analyses of particular coastal areas in order to assess or monitor the possible impacts currently affecting areas dedicated to aquaculture, or issue permits for new cultivation areas.

The GIS tool developed in this case study, together with the methodology and data used, were demonstrated during an inspection of the work and at the seminar held at CETMAR on 23 June 2011. In this first presentation of the case study, the main aspects taken into consideration and the main results obtained were demonstrated. The tool was also presented at a visit organised by Marennes-Oléron to demonstrate the results to the regional and local administration and professionals working in the fisheries and shellfish harvesting sector in the area.

In addition, to make the tool more widely applicable and useful, it was included in an interactive viewer at http://ancorim.xeogalicia.net/, with the aim of making it available to coastal zone administrations and managers.
Section 3 – Governance structures and scientific community

3.1. Management and competences in the Galician coastal areas

The normative that governs coastal areas in Spain is the Law of the Coast 22/1988 of 23 July, (BOE 19/07/1988) which includes the European recommendations for the protection of coastal areas. In Galicia, the competences related with coastal management and planning are shared between the central and the regional government. The Central Government through the General Directorate of Sustainability of the Coast and the Sea (Dirección General de Sostenibilidad de la Costa y del Mar), from the Ministry of Environment, Rural and Marine Affairs (Ministerio de Medio Ambiente y Medio Rural y Marino), is responsible for the management of the Maritime-Terrestrial Public Domain and the granting or denial of permits in the Easement Transit and Access to the sea and in the maritime-terrestrial public domain declared by the Estate, with the exceptions of the competences assumed by the regions. The central government is in charge of the protection and conservation of the elements that integrate the maritime-terrestrial public domain, in particular the sustainable adaptation of beaches, dunes and coastal wetlands, and the drafting, implementation, monitoring, control and inspection of studies, projects and works of coastal defense.

The autonomous region of Galicia has jurisdiction over the authorization of uses in the Easement protection (transferred from the administration) through the Law 9/2002 of urban planning and rural environmental protection in Galicia, amended by Law 2/2010 on urgent measures and local regulations on urban planning. This normative establishes the coordination mechanisms of the administrations that share competences in the planning of coastal actions in the region. Specifically, the Regional Ministry of Environment, land and infrastructure (Consellería de Medio Ambiente, Territorio e Infraestruturas) has a particular role on the management of the coast of Galicia since many of their duties and responsibilities directly affect it (Royal Decree 316/2009). Particularly in relation to the planning and management of coastal areas, water resources and landscape, the General Secretariat of Planning and Urbanism (Secretaría Xeral de Ordenación do Territorio e Urbanismo) has developed planning instruments such as the Coastal Management Plan (Plan de Ordenación del Litoral). Its approval procedure will comply with Article 5 bis and 15 of Law 10/1995 of 23 November.

The management of coastal areas at local level is shared with the local municipalities. In Galicia, the 74 coastal municipalities are governed by the law 5 / 1997 of 2 July, of the Local Government of Galicia. Urban issues in the Area of Influence are the responsibility of municipalities. They also are in charge of the provision of parking areas and adequate access to
the sea (except in areas of special protection.) The municipalities also assume the competences over the control and maintenance of bathing areas and bathing water quality.

**Water quality and coastal activities**

Water administration in Galicia is regulated by the Law 9/2010 of 4th November of Aguas de Galicia, establishing that the Autonomous community of Galicia has responsibility and competences for water issues and hydraulic works in the region. Specifically, within the Regional Ministry of Environment, Territory and Infrastructures (Consellería de Medio Ambiente, Territorio e Infraestruturas), the competences in the field of quality of coastal, continental and transitional waters in the Galicia Catchment area are developed by the autonomous entity "Augas de Galicia" (Decree 316/2009 and 108/1996). One of the main activities of “Augas de Galicia” is the implementation of the European Water Framework Directive and the development of the Hydrological Plan of the Galician Coast (Plan Hidrológico de Galicia-Costa) which was approved by Royal Decree 103/2003, and must be replaced by the new Hydrological Plan developed according to the mandates of the European Water Framework Directive that has been recently submitted for public review and information.

As part of the Regional Ministry of Environment, land and infrastructures, the General Secretariat of Environmental Assessment and Quality has created the Environmental Observation Network (Red de Observación Ambiental, ROAGA) which constitutes the monitoring network of the ecological status of the Galician waters by the acquisition and processing of environmental information.

Regarding marine resources, the Regional Ministry of the Sea (Consellería do Mar) has exclusive competence in the management of fisheries (both professional and sportive) in inland waters, shellfisheries and aquaculture (Decree 312/2009) and has developed legal instruments for their management: Law 11/2008 of Fisheries in Galicia, the Galician Plan of Aquaculture (Plan Gallego de Acuicultura) published in the Resolution of 12th September 2008 and the General plan of Shellfisheries Exploitation (Plan General de Explotación Marisquera) created in 1992.

It should be mentioned the importance of the fishermen Guilds (Cofradías de pescadores) which in Galicia have deep traditional and historical importance. According to the Law 9/1993, of 8th July, the Cofradías can be defined as public law corporations, with own juridical status and capacity to exercise their functions. They elaborate their own Annual Exploitation Plan for the management of the marine resources included in their area of competence, which is reviewed and approved by the Dirección Xeral de Recursos Mariños (Regional Ministry of the Sea).
The competences of the Regional Ministry of the Sea are transferred from the central government, and also include the fight against marine pollution and the development of the **Regional Contingency Plan for Marine Pollution in Galicia**, approved by Resolution of April 23, 2007 in compliance with the Order of February 23, 2001. This regional plan was elaborated by the General Subdirector of Coastguards of Galicia (**Subdirección Xeral de Gardacostas de Galicia**), who is also in charge of the inspection, prevention and application of correction measures regarding fisheries, shellfisheries and aquaculture. The service has also competences on maritime rescue acting in case of emergencies in the maritime environment and performs the necessary functions in combating accidental marine pollution, through prevention, detection, and elimination of marine spills.

As part of the Regional Ministry of the Sea, the Technical Institute for the Control of the Marine Environment (**Instituto Tecnolóxico para o Control do Medio Mariño, INTECMAR**) carries out the monitoring, control and investigation of the environmental quality of coastal waters of Galicia for the development of aquaculture activities. It also develops initiatives in the field of operational oceanography and in combating marine accidental pollution and it is integrated in the Regional Contingency Plan for Marine Pollution in Galicia through the Unit of Documentation and Scientific Support and the Unit of Onshore Surveillance.

Finally, when analyzing competences in coastal planning and coastal activities, it is necessary to consider port infrastructures, because of its great socioeconomic importance and significant relevance in coastal areas. In the Galician coast there exists 128 ports, 6 of which (of bigger dimensions and considered of “general interest”) are managed by Port Authorities from the public body State’s Ports on behalf of the Ministry of Development of the Spanish government (Law 27/1992 of 24 November, of State Ports and the Merchant Marine, and Law 33/2010, of August 5, to amend the Law 48/2003 of November 26 on the economic regime and service delivery at the ports of general interest). The resting 122 are directly managed by the Galician government, through the public body “Galician Ports”, who has competences over their planning, construction, exploitation, conservation and development.

**Environmental competences, protected areas and conservation of natural resources**

The competences about environmental protection are shared between the Regional Ministry of environment, land and infrastructures (**Consellería de Medio Ambiente, Territorio e Infraestruturas**) in accordance with Decree 316/2009, and the Regional Ministry of Rural Environment (**Consellería do Medio Rural**), Decree 318/2009. As part of the Regional Ministry of Environment, land and infrastructures, the General Secretariat of Environmental Assessment and Quality (**Secretaría General de Calidade e Avaliación Medioambiental**) has competences on environmental protection, promotes the sustainable development in the Galician region, and
it is in charge of the protection, planning and management of landscape (Decree 316/2009). It has developed the Galician Framework Programme on Climate Change 2010-2020 (Programa Marco Gallego frente al Cambio Climático) aimed to help to achieve the objectives of the European Union and Galicia for the compliance of the Kyoto Protocol.

The General Directorate of Nature Conservation (Dirección Xeral de conservación da Natureza) from the Regional Ministry of Rural Environment exercise the competences and functions in the conservation, protection, sustainable use, improvement and restoration of natural heritage and biodiversity of Galicia and its ethnographic elements, and the specific conservation of natural areas included in the Galician Network of Protected Areas and Natura 2000 Network of Galicia or other areas of high environmental value (Decree 318/2009). The natural protected areas in Galicia are managed according to the Law 97/2001 of 21st August of Nature Conservation.

**Collaboration and cooperation of the regional administration and the scientific community in the development of planning instruments**

The preparation of planning instruments such as the Coastal Management Plan, often requires the advice of the scientific community for its elaboration and definition. Regional and local administrations request the cooperation of research groups from Galician research institutions that have largely collaborated in the definition of legal instruments, however, there does not exist a legal framework establishing cooperation criteria and mechanisms.

Many legal Instruments such as the Regional Contingency Plan for Marine Pollution in Galicia, or the Regional Emergencies Plan include the creation of an advisory board to be consulted in case of emergency. For example, the Regional Contingency Plan establishes the creation of a Technical Support Unit that may include not only representatives from technical Institutions such as INTECMAR, Ports of Galicia, MeteoGalicia Augas of Galicia, etc, but also other technical advisors and scientists from the Universities or Public Research Organizations.

**3.2. Contribution of the case study to the links between decision-makers and the scientific community**

The use of Geographic Information Systems is increasing considerably as a tool for integration and homogenization of large amounts of information from various sources into georeferenced databases. These databases can incorporate and correlate geographic, scientific and socioeconomic information of interest in the planning and support of the decision-making process. The analysis of crossed information allows easy access to data and results, and allows the creation of thematic maps and the development of geostatistical analysis.
In coastal areas, geographic information systems have an enormous potential to contribute to coastal management. The present case study is based on the use of a geographical information system that allowed the incorporation, conversion, processing and storage of an important amount of relevant information concerning the coastal zone and coastal activities in the Ría de Vigo. The information integrated in the study collected from various sources is translated and interpreted to facilitate its visualization and use. The case study serves as link between managers and scientists since it collects and translates information obtained from scientific sources and makes it available to coastal managers in the form of maps that combine all the information processed.

The geo-referenced scientific data reflected in the maps included in the case study allows a quick visualization of the information, which may be updated or displayed in a suitable or desired format. The case study compiles information obtained on the littoral zone and coastal waters of the ría, related with land uses and the various economic and social activities developed on the coast (location of urban areas, beaches, maritime transport routes, etc), bathymetry, currents, etc. This information not only provides a visual inventory of the coastal environment but also a support for the manipulation of the information available. From the volume of information compiled and updated, only the relevant information for the study was selected and considered in order to focus on the potential sources of risks that could have an effect on aquaculture.

The variables selected for studying potential sources of risk have been weighted according to the importance initially given to each of the layers used in the analysis. The weights of the different variables can be modified according to the criteria of decision-makers, obtaining different results depending on the importance given to each variable. The system also allows the introduction of other variables to evaluate its effect on the system.

Despite the many applications of GIS in spatial decision support for coastal management, their use among coastal stakeholders and decision makers is still very low. The objective of this case study is to show the high potential of the use of Geographical Information Systems in the management of coastal information obtained from diverse and different sources (scientific information, land use, socioeconomic information, etc) translated and interpreted to facilitate the decision-making process, and giving the possibility of creating different scenarios in the search of solutions.

3.3. References

Section 4: Executive summary

4.1 Justification and objectives of the case study

Galicia, and in particular the group of the Rias Baixas, in the northwest coast of Galicia have very suitable conditions for aquaculture due to their high biological productivity, which is related to their hydrographic and oceanographic conditions and the presence of upwelling events in their coastal waters. This high primary production favours the cultivation of marine organisms in their coastal waters and due to this aquaculture is a very important socioeconomic activity in the Galician region. The particular geomorphology and oceanographic conditions of the rías have allowed the installation of floating cultivation rafts, in which mussel farming is being carried out since 1946. According to the Decree 197/1996 of 12 June, mussel rafts are located in cultivation areas or polygons within the rías where each raft has a maximum surface of 550 m$^2$, with a restriction of 500 ropes of a maximum length of 12 meters. In the Ría de Vigo, there exists 478 rafts located in 13 cultivation polygons, which are mostly used for mussel farming, but also a minority of them is being used for the growing of other mollusc such as oyster, clams, etc.

Apart from aquaculture, the coastal area of the Ría de Vigo concentrates a high number of social and economic activities: port activities, shellfisheries (in intertidal and subtidal areas), fishing, fish and shellfish processing industry, maritime transport, tourism, recreational sports, location of urban areas, sewage plants and waste collectors (urban and industrial), etc. As a result of this intense overlapping of coastal activities, the management of the coastal zone is highly complex.

The objective of this case study is to identify potential sources of risks that may affect aquaculture floating facilities in the Ría de Vigo and calculate suitability indexes for their current location.

To do so, the overlapping of activities is here analyzed and the potential sources of risks for cultivation areas identified. In order to analyze the compatibility of the different activities, a hierarchical weighted model for suitability analysis was applied giving different weights to the different sources of risks considered. The tool is based on GIS analysis and multicriteria evaluation (MCE) and it considers the distance from the aquaculture sites to other economic activities making use of coastal areas: maritime transport routes, urban areas, port activities, recreational sports, tourism, waste collectors, etc showing the most suitable areas for the predefined cultivation sites in the Ría (the results of the analysis were applied to the areas where floating farms are currently allowed). The case study also considers the variation of other variables such as water temperature and salinity in coastal waters giving different scenarios for each season.
4.2 Transference of the tool to other coastal regions

The sustainable development of aquaculture largely depends on the selection of suitable sites for cultivation (GESAMP 1996). The selection of the suitable sites should consider socioeconomic factors such as the needs of infrastructures, materials, transportation routes, distance to markets, etc, environmental factors: temperature and salinity conditions, currents, tides, depth, etc, and also it should be taken into account the potential impact that they could produce on the environment. Apart from these factors, the selection of suitable sites need to consider the high demand and competition for space in coastal areas, and the important overlap of multiple socio-economic activities that are usually developed in littoral areas. Coastal aquaculture should be managed according to a scheme of Integrated Coastal Zone Management (ICZM) where any proposed marine aquaculture plan or policy should integrate an adequate location system (GESAMP 1991, 1996). Such a system should take into account all economic, social and environmental factors in order to ensure the success of marine cultures.

The present case study focuses on identifying the most suitable sites for the location of culture floating structures (rafts) in the ría, taking into account the distance to other economic activities developed on the coast. In the study area, only those coastal economic activities that may have a potential impact on aquaculture have been considered and evaluated.

The methodology proposed in this case study can be transferred to other areas where there exist a need to identify the most suitable sites for cultivation considering the potential impact caused by other coastal activities. The tool developed could be useful for coastal authorities and managers who need to perform spatial analysis in certain coastal areas, both for the assessment and monitoring of the impacts that may affect current cultivation areas, or for issuing new aquaculture permits.

The implementation of the tool in other regions would require a detailed review and identification of the particular socio-economic activities developed on the area, and the compilation of geographic information related to these activities. Given the variety of units and scales of measurement for each variable or activity, the multicriteria decision analysis requires that the values are transformed into comparable scales and units by normalization of each variable and setting a variation range of continuous values between zero and one. Finally, the preferences of regional decision-makers will be included in the model, giving a relative weight to each variable,
which will vary in each study area depending on the variables considered and their relative importance at regional level. The calculation of the weights of each variable is based on the importance assigned to each variable and will be a subjective value according to the criterion of coastal managers and decision makers. The weight value is calculated from the pairwise comparison method developed by Saaty (1994). The variables taken into account, and their relative importance is combined using multicriteria evaluation (MCE) using linear combination of the sum of the weighted variables under consideration (see the methodology section for a detailed description).

4.3 Contribution of the case study to the links between decision-makers and the scientific community

The use of Geographic Information Systems is increasing considerably as a tool for integration and homogenization of large amounts of information from various sources into georeferenced databases. These databases can incorporate and correlate geographic, scientific and socioeconomic information of interest in the planning and support of the decision-making process. The analysis of crossed information allows easy access to data and results, and allows the creation of thematic maps and the development of geostatistical analysis.

In coastal areas, geographic information systems have an enormous potential to contribute to coastal management. The present case study is based on the use of a geographical information system that allowed the incorporation, conversion, processing and storage of an important amount of relevant information concerning the coastal zone and coastal activities in the Ría de Vigo. The information integrated in the study collected from various sources is translated and interpreted to facilitate its visualization and use. The case study serves as link between managers and scientists since it collects and translates information obtained from scientific sources and makes it available to coastal managers in the form of maps that combine all the information processed.

The geo-referenced scientific data reflected in the maps included in the case study allows a quick visualization of the information, which may be updated or displayed in a suitable or desired format. The case study compiles information obtained on the littoral zone and coastal waters of the ría, related with land uses and the various economic and social activities developed on the coast (location of urban areas, beaches, maritime transport routes, etc), bathymetry, currents, etc. This information not only provides a visual inventory of the coastal environment but also a support for the manipulation of the information available. From the volume of information compiled and updated, only the relevant information for the study was selected and considered in order to focus on the potential sources of risks that could have an effect on aquaculture.
The variables selected for studying potential sources of risk have been weighted according to the importance initially given to each of the layers used in the analysis. The weights of the different variables can be modified according to the criteria of decision-makers, obtaining different results depending on the importance given to each variable. The system also allows the introduction of other variables to evaluate its effect on the system.

Despite the many applications of GIS in spatial decision support for coastal management, their use among coastal stakeholders and decision makers is still very low. The objective of this case study is to show the high potential of the use of Geographical Information Systems in the management of coastal information obtained from diverse and different sources (scientific information, land use, socioeconomic information, etc) translated and interpreted to facilitate the decision-making process, and giving the possibility of creating different scenarios in the search of solutions.