Theme Methods and Applications for Integrated Coastal Zone Management
Sub theme Thematic Applications

SUSTAINABLE COASTAL HABITATS: GIS TOOLS FOR EFFECTIVE DECISION SUPPORT.

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Introduction

In the late twentieth century European Union authorities were facing the challenge of adhering to the Habitats Directive (92/43/EEC) and looking for ways to fulfil its objectives. The Directive was adopted in 1992 and the governments of the European Union committed themselves to the creation of an ecological network, the NATURA 2000 network, with the aim of conserving a breadth of European habitat types and wildlife species. In doing so, they set in motion potentially the most significant initiative for nature conservation in the history of Europe.

The NATURA 2000 network is made up of Special Protection Areas (SPAs) and Special Areas of Conservation (SACs). SPAs are designated under Directive 79/409/EEC (commonly known as the Birds Directive) and ensure the protection of Annex I bird species. SACs are designated under Directive 92/43/EEC (commonly known as the Habitats Directive). SACs are designated in relation to habitats of Annex 1 and species of animal and plant of Annex II of the Habitats Directive.

The ambitious NATURA 2000 network epitomises the European Union's drive towards long-term sustainable nature conservation. The aim, to create a European network of biodiversity excellence to ensure the long-term protection of endangered plant and animal species, and threatened natural habitats, is laudable, but ultimately challenging.

The focus of this project is to develop tools to facilitate the management of environmentally sensitive coastal habitats, utilising the breadth of information available on the habitat and species status of NATURA 2000 sites. Data pertaining to Coastal NATURA 2000 sites are input to a Geographical Information System (GIS), which is the principal device used to house the database and to produce a GIS based Sensitivity Analysis Model. The project output will be a tool that can be used to calculate the threats to, and evaluate the impacts on, environmentally sensitive coastal habitats.

This paper will present an overview of efforts to quantify environmental sensitivity in addition to outlining the potential data and information that exists in NATURA 2000 Standard Data Forms, which can be used for this purpose. Finally, a conceptual model for mapping is presented. The phases of the project are outlined in the methodology section.

Quantifying Sensitivity

Work to date on coastal classification, quantifying sensitivity and the development of sensitivity indices has focused primarily on oil spill risk/sensitivity, sea level rise and coastal erosion (e.g. Getter, C. 1981; Gornitz, V. 1990; Jensen, J.R, 1990).

Cooper and McLaughlin (1998) reviewed 18 published accounts of coastal classification procedures and noted the main differences identified between the indices are in terms of scale of application, variables included, mode of analysis, mode of presentation and the nature of the risks assessed. In general it was concluded that few indices adequately considered the physical basis for interaction between variables used in the classification procedure.

Prioritising sensitive areas of the coast has been an important part of oil spill contingency planning since the 1970s and a lot of work has been carried out on the ranking of sensitivity. The Environmental Sensitivity Index (ESI) is a ranking of the relative sensitivities of various geomorphic coastal environments in terms of oil-sediment interactions. Traditional ESI mapping techniques involved the uses of already existing planimetric base maps and the subsequent identification of shoreline and biological sensitivity areas, as well as the locations of access-protection facilities (Getter *et al*., 1981). More recent work on ESI mapping has involved the use of remote sensing and GIS technology to make it a more effective and efficient tool (Jensen *et al.*, 1990; Jensen *et al*., 1993).

Gornitz (1990) developed a Coastal Vulnerability Index (CVI) for the east coast of the USA to determine areas vulnerable to sea level rise. The index includes the input of several variables into a GIS that relate to coastal erosion and inundation and these are given a ranking. Algorithms are used to obtain CVI's. This CVI was utilised in further instances by Gornitz such as in the development of the Coastal Risk Assessment Database for the southeast US coast in 1993 and a Coastal Hazards Data Base for the US west coast in 1997. Variations on the initial CVI methodology were employed involving multiple regression analysis and weightings.

Biological sensitivities of various marine communities are described in reports such as the 'Sensitivity of Marine Communities to Man Induced Change' (Holt *et al*., 1995). Various marine communities and their characteristics and sensitivities are described and sensitivity scales and scoring systems discussed.

Within the current EU campaign to identify vulnerable ecological areas, surveyors are collating vast quantities of data on habitats and species. Large quantities of attribute data are collected from each site, including information on non-Annex I/II species and impacts on site, when pre-designated EU sites are being assessed. A gap of knowledge exists in relation to sensitivity analysis and the protection and management of legally designated coastal habitats. Data that could be used in the ongoing management & impact control of designated sites, collected on NATURA 2000 Standard Data Forms, Europe-wide, becomes defunct in the management process for opportune site protection. The research is attempting to address this gap by developing GIS tools for such decision support.

NATURA 2000 Standard Form Information

The Standard NATURA 2000 forms contain a rich source of information about the sites that they are assessing. Standard information includes site identification codes and information about the site location/administrative region. The remainder of the information is descriptive of the ecology and species on the site, along with the impacts on and around the site.

A single NATURA 2000 Standard Data Form is completed for each designated site. Figure 1 is a diagrammatical representation of the level of data collected. Each site may be designated due to the presence of one, or scores of, protected habitats and/or species.

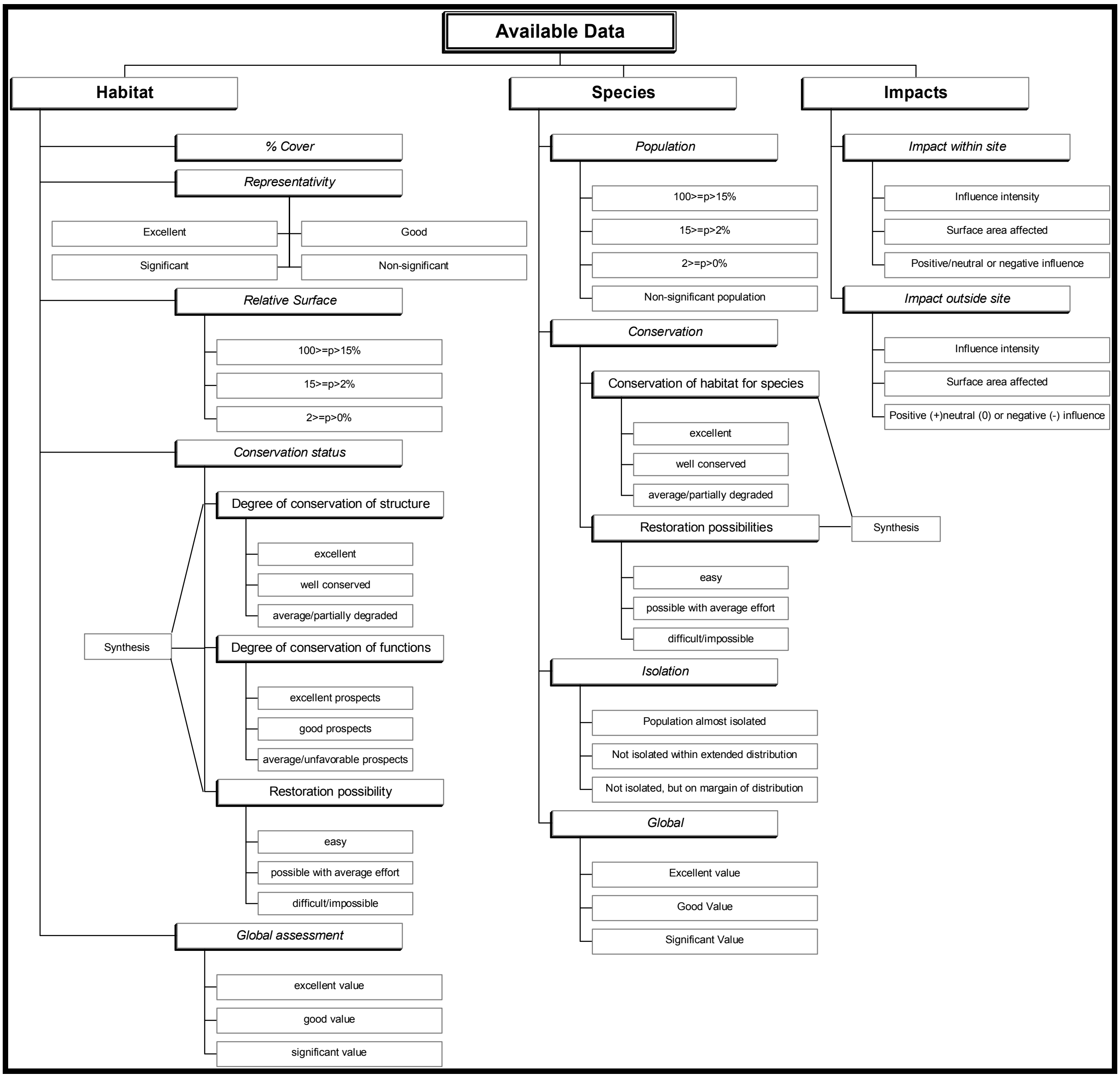


Figure 1. A diagrammatic representation of the collated data from NATURA 2000 Standard Data Forms. Depending on the number of designated habitats, species or impacts, any of the Habitats/Species branches of information may be completed numerous times for each site. Each of these branches will have an associated Impact branch.

Full descriptions of each of these attributes are available from the European Union website. http://europa.eu.int/comm/environment/nature/natura_standard_forms.htm

Data Available on NATURA 2000 Standard Data Forms

1. **Ecological Information**
2. **Species Information**
3. **Impacts in/around site**

1. Ecological Information

Information on the ecology (Habitat Directive Annex 1) includes the following

a) **Percentage Cover -** The percentage cover of each habitat that is described. A number of habitats can be described in this section.
b) **Representativity -** The degree of representativity of the natural habitat type on the site. The degree of representativity gives a measure of 'how typical' a habitat type is. If need be, this assessment should likewise take into account the representativity of the habitat type concerned on the site in question, either for a group of habitat types or for a particular combination of different habitat types.
c) **Relative Surface -** The area of the site covered by the natural habitat type in relation to the total area covered by that natural habitat type within the national territory.
d) **Conservation status –** The degree of conservation of the structure and functions of the natural habitat type concerned, and restoration possibilities.
e) **Global assessment –** The global assessment of the value of the site for conservation of the natural habitat type concerned. The 'most relevant' elements may vary from habitat type to habitat type; they may include the human activities, both in the site or in its neighbouring areas, that are likely to influence the conservation status of the habitat type, the ownership of the land, the existing legal status of the site, the ecological relations between the different habitat types and species, etc.

2. Species Information

Information on the species includes the following:

a) **Population –** The size and density of the population of the species present on the site in relation to the populations present within national territory. This criterion exists to evaluate the relative size or density of the population in the site with that of the national population.
b) **Conservation –** The degree of conservation of the features of the habitat, which are important for the species concerned, and possibilities for restoration
c) **Isolation –** The degree of isolation of the population present on the site in relation to the natural range of the species. This criterion may be interpreted as an approximate measure of the contribution of a given population to the genetic diversity of the species on the one hand and of the fragility of this specific population on the other hand.
d) **Global –** The global assessment of the value of the site for conservation of the species concerned. This criterion refers to the global assessment of the value of the site for the conservation of the species concerned. It may be used to sum up the previous criteria and also to assess other features of the site thought to be relevant for a given species. These features may vary from one species to another and might include human activities on the site or in nearby areas which are capable of influencing the conservation status of the species, land management, the statutory protection of the site, ecological relations between the different types of habitats and species, etc.

3. <u>*Impacts In/Around the Site*</u>

Impacts relate to all human activities and natural process that may have an influence, either positive or negative, on the conservation and management of the site. Appendix E of the NATURA 2000 Form gives a list and equivalent code for each impact.

Information on impacts includes the following:

a) **Intensity;**
b) **Surface area covered;**
c) **Influence (+, 0, -)**

Also described are the impacts and activities in the surroundings of the site. The 'surroundings' is the area where the outside impacts and activities may affect the integrity of the site. It will depend among other things on local topography, the nature of the site and on the type of human activities.

Methodology

The methodology has been developed in a number of Phases. The proposed model will be tested and implemented according to the outline below.

The project is using coastal NATURA 2000 sites in County Cork, Ireland, to develop the prototype model. The aim of the GIS based generic Sensitivity Analysis Model is to take into account the influence of a threat (e.g. overgrazing, pesticides, peat cutting) on specific habitats and specific species and calculate this with the realised threat (and its intensity) at the particular designated site.

A project specific GIS (Figure 2) was designed to house and manage a broad ranging spatial database, and as a developmental tool in the production of a GIS based Sensitivity Analysis Model. The GIS contains numerous data layers including: 1:50,000 and historical base mapping; Corine land classification data; ortho photography and scanned historic aerial photography; EU nature designations including SPAs, SACs, NHAs, Nature Reserves & National Parks and coastal NATURA 2000 sites. The Sensitivity Analysis Model will be self-contained within the GIS, thereby allowing direct visualisation of model results. ESRI's ArcInfo and Microsoft's Visual Basic for Applications are being used to develop the GIS Sensitivity Analysis Model. Figure 3 outlines the Phases of the model development.

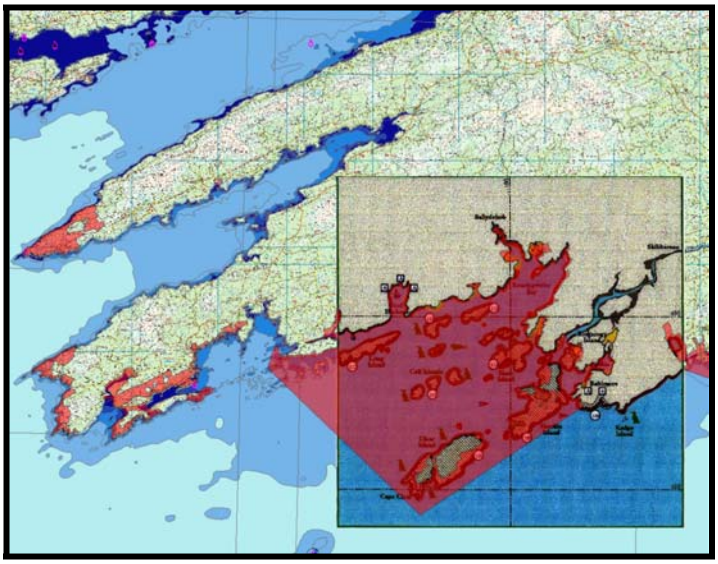


Figure 2. A snap shot of data layers in the GIS; layers include base mapping, oil spill sensitivity mapping, and NATURA 2000 sites.

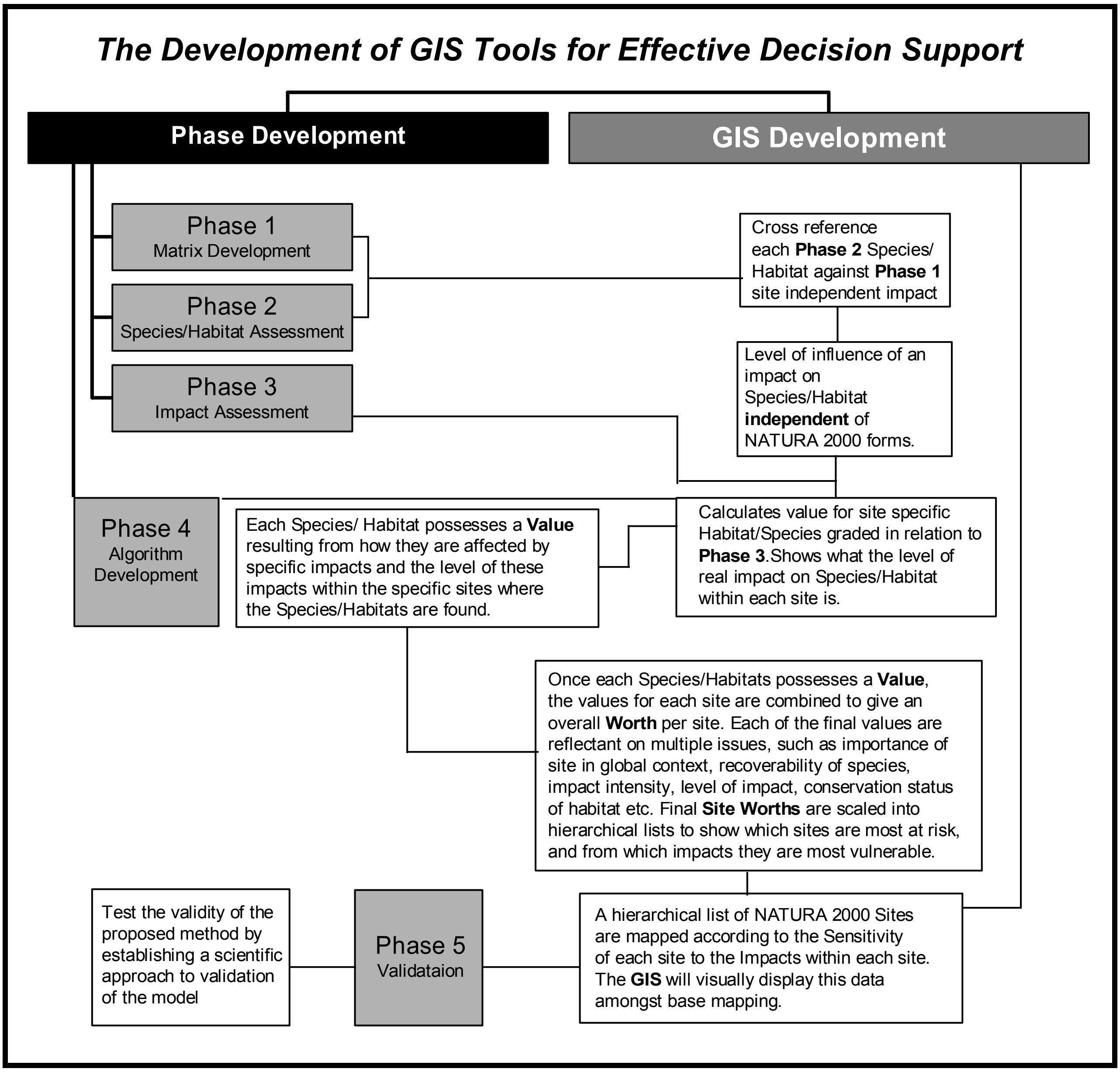


Figure 3. A diagrammatic representation of the Development of GIS Tools for Decision Support.

Phase 1 – Matrix Development

NATURA 2000 site impacts are extracted from the NATURA 2000 Data Forms. Unfortunately these impacts are not related directly to any habitat or species within the site, however, each impact has a number of attributes tagged to it, such as intensity & influence. Therefore, Phase 1 involves the development of a matrix (Figure 4) of impact-species-habitat intensity. A cross-reference system will allow an expert to input values of 'high', 'moderate', and 'low' and 'no impact' to either a habitat or species from a particular impact. For example, grazing may have a 'high' impact on fixed dune systems but a 'low' impact on embryonic dune systems.

A number of methods to create the matrix are under investigation, including Saaty's method of Pairwise Comparison. Because of the high level of time required conducting a pairwise comparison it might be preferential to follow a process of direct cross-reference of habitat/species against impact. A matrix will also be completed for impacts that occur in proximity to the sites, for example a site may not contain agricultural land but if agricultural land is in proximity then pollution via runoff may possibly impact the designated site.

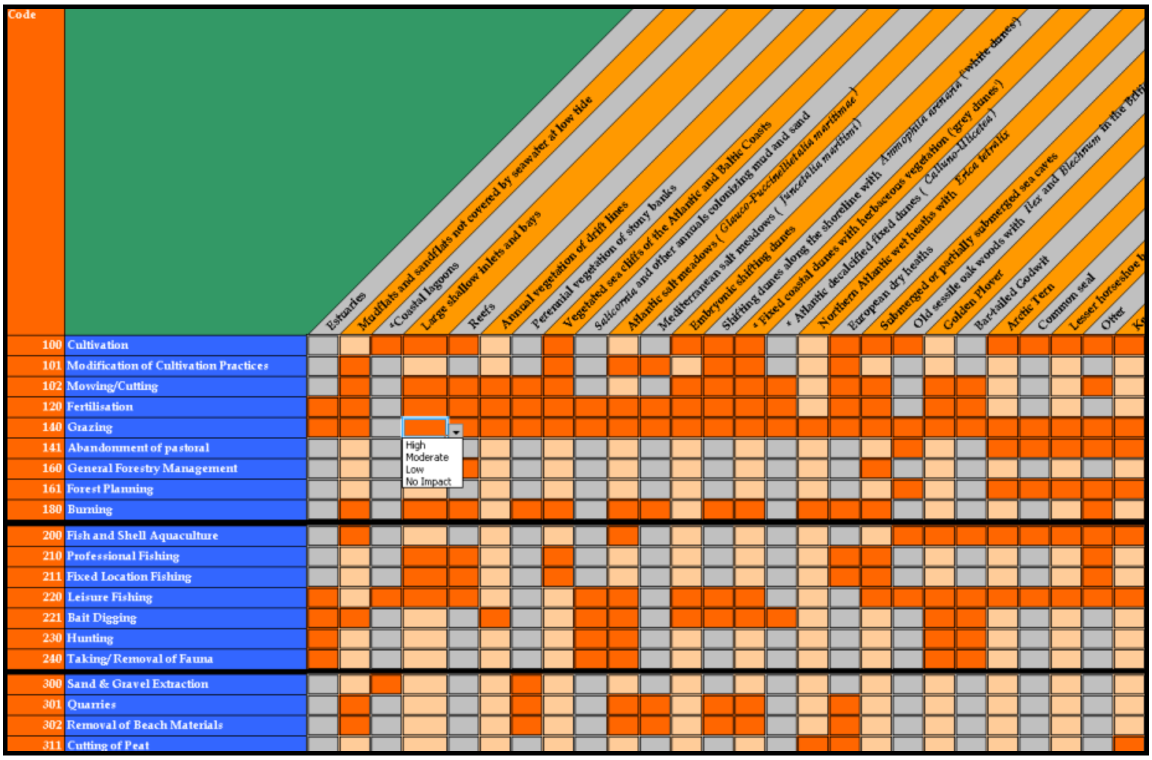


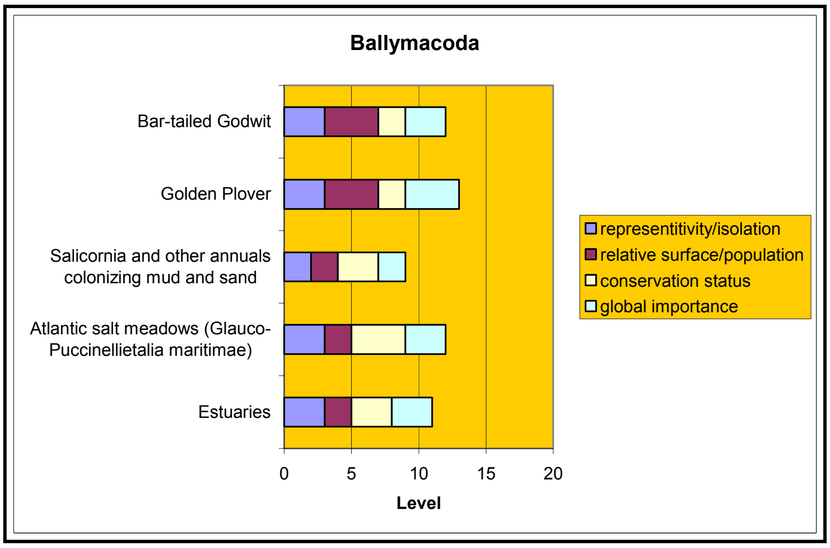
Figure 4. Matrix of Impact – Species – Habitat Intensity

Phase 2 – Species/Habitat Assessment

As shown in Figure 1, a great deal of information is gathered for each habitat/species within each site. Some habitat/species have a greater importance attached to them than others, whether due to higher global importance, conservation status or restoration possibilities. Phase 2 analyses each habitat/species in relation to the information gathered during the designation process and grades each of them. Table 1 illustrates the initial process of grading for Ballymacoda, a NATURA 2000 Site in County Cork. Graph 1 is an example of visual interpretation (using numerical values) of Ballymacoda's habitats and species tagged to their representativity/isolation, relative surface area/population, conservation status and global importance.

Species/habitat	Name	representitivity/isolation	relative surface/pop	conservation status	global
1130	Estuaries	b	c	b	b
1330	Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*)	b	c	a	b
1310	*Salicornia* and other annuals colonizing mud and sand	c	c	b	c
a140	Golden Plover	b	a	c	a
a157	Bar-tailed Godwit	b	a	c	b

Table 1. An example of data collected on the NATURA 2000 Standard Data Forms in relation to Species & Habitats for Ballymacoda.



Graph 1. A visual interpretation of Ballymacoda's habitats and species tagged to representativity /isolation, relative surface area/population, conservation status and global importance.

Phase 3 – Impact Assessment

The NATURA 2000 forms, as previously stated, contain information on the impacts within and around each site. These impacts are not related to a specific habitat or species within the site on the form. One problem with this is that an impact may have a great influence on one species and no influence on another species, thus the importance of mitigating against the impact is unknown unless species/habitat specific impacts are analysed. Phase 3 assesses the identified impacts in each site using level and influence values from the forms. Table 2 illustrates the data available in the forms regarding the impacts within and surrounding the site for Ballymacoda. Graph 2 is an example of visual interpretation (using numerical values) of impacts at Ballymacoda.

Where are impacts	Code	Impacts	Level	Influence
inside	120	Fertilisation	b	neg
inside	140	Grazing	b	neg
inside	220	Leisure Fishing	b	neutral
inside	221	Bait Digging	c	neg
inside	230	Hunting	b	neg
inside	240	Taking/ Removal of Fauna	c	neg
inside	607	Sports Pitch	b	neg
inside	622	Walking, Horse Riding	b	neg
inside	810	Drainage	b	neg
inside	952	Eutrophication	c	neg
inside	954	Invasion by species	b	neg
outside	120	Fertilisation	b	neg
outside	140	Grazing	b	neutral
outside	403	Dispersed Habitation	b	neutral

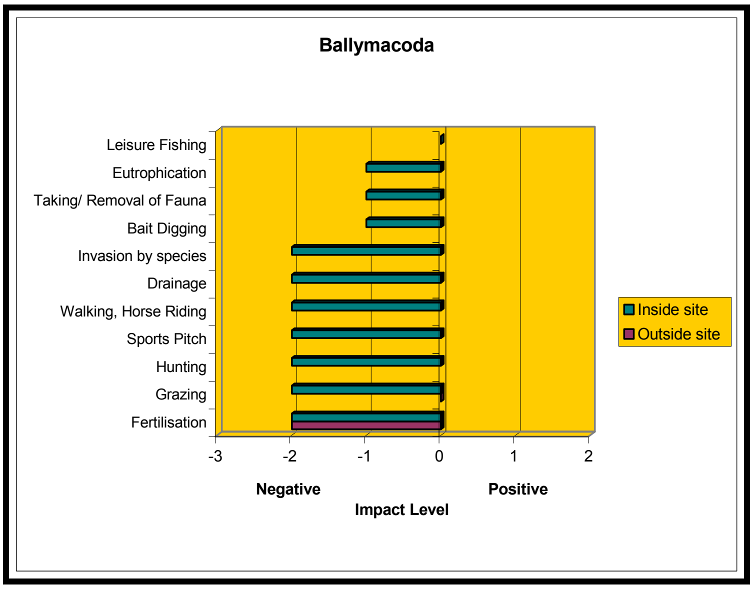


Table 2. A range of impacts in Ballymacoda affects the site, many having a negative influence. **Graph 2.** Visual interpretation of impacts within and around Ballymacoda.

Phase 4 – Algorithm Development
Phase 4 is the process of generating an algorithm to assist in the coalescing of discrete data from Phases 1-3. A value will be calculated for each site specific Habitat/Species graded in relation to Phase 3. This value will show what the level of the real impact on a Species/Habitat within each site is. Within the model, once each Species/Habitats is assigned a value, the values for each site are combined to give an overall total value per site. Each of the final values reflect multiple issues, such as importance of site in the global context, recoverability of species, impact intensity, level of impact, conservation status of habitat etc. Final site values are scaled into hierarchical lists to show which sites are most at risk, and from which impacts they are most vulnerable. A hierarchical list of NATURA 2000 Sites is mapped according to the Sensitivity of each site to the Impacts within and surrounding each site. The GIS will visually display these results.

Phase 5 – Validation
Work to date has focussed on assessing the potential and content of data available from NATURA 2000 Standard Data Forms to develop a methodology for assessing environmental sensitivity. The step-by-step methodology that has been identified is under implementation. The most important element of future work will be to test the validity of the proposed method by establishing a scientific approach to validation of the model. This will ascertain if the methodology works. Already there are key issues that need to be addressed. These are outlined in the discussion section.

Discussion
The emphasis of the project is the application of technology to environmental protection and conservation, principally, the sustainability of coastal habitats and resources. By attempting to develop a generic GIS based Sensitivity Analysis Model as a decision support tool, we hope to provide a means to exploit non-operational data archives to aid in the continuous management of areas that have been afforded the opportunity of conservation.

Due to the fact that the decision support tool development is ongoing, it is envisaged that hurdles will be met in relation to several of the phases outlined in the paper. The generation of data for Phase 1 requires the input of expert opinion because of a lack of readily accessible alternative data availability. By gathering data from a number of experts a statistical approach to matrix development can be achieved. Limitations of this approach are intrinsically linked with the human factors associated with the reliance on experts with different opinions and interpretations.

The greatest obstacle faced in the study is the development of a coalescing algorithm in Phase 4. In other sensitivity assessment studies (e.g. Cooke & McMath, 2001) the main difficulty in creating an algorithm that encompasses all of the correlated characteristics was due in part to a necessity to include important indicators such as keystone species and incorporate numerical values to cover areas such as the recoverability of a species. Fortunately, the Standard Data Forms include attributes of a species in each specific site so that information such as conservation status, restoration possibility, degree of conservation and representativity are all included in the site-specific species information. The main concern within Phase 4 is the allocation of qualitative values to non-qualitative objects. By investigating proven statistical techniques it is envisaged that these foreseen problems can be overcome.

This research is an attempt to maximise the potential of data that is already available. It is an experiment that, if successful, may assist future management of a multitude of protected areas. This project is due for completion in 2004.

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