KnowSeas

Knowledge-based Sustainable Management for Europe's Seas

Deliverable 2.3: Design of Decision Space Analysis

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Contents

What we've got here is a failure to communicate (the importance of spatial and temporal scale mismatches in implementation of the ecosystem approach).

1. INTRODUCTION

The Ecosystem Approach to management (EA) has gained the interest of scientists and managers as a potential framework for integrating environmental and other management concerns (MEA, 2005). There is no universally accepted definition of the approach though several characteristics are common to most descriptions including: a multi-sectoral focus; inclusion of ecosystem services within the decision making process and a recognition that human and ecological systems are tightly coupled (Tallis et al., 2010). Essentially the approach recognises that in order to be sustainable the social system must work within the bounds of the ecological system which contains it (Boumans et al., 2002). Despite the strong conceptual basis for the EA and formal adaptation of the approach by numerous institutions around the world (Murawski, 2007) there is a scarcity of success stories. The increasing focus on managing the environment as a combined social-ecological system has led to an increasing awareness that the spatial and temporal scales of social systems frequently do not match those of the ecological decisions they are charged with managing (Cumming et al., 2006; Pelosi et al., 2010). Understanding such spatial and temporal mismatches and communicating them to decision makers is key to effective implementation of the ecosystem approach. While examples do exist of the ecosystem approach in practice (Tallis et al., 2010) and common standards are developing, the broader success and viability of the approach as a general management paradigm will be dependent on a systematic approach to understanding and integrating considerations of spatial and temporal mismatch within the decision making process.

Implementing the EA is ambitious: accounting for multi-sectoral objectives, examining the trade-offs between human welfare and environmental quality and understanding the ecosystem implications of management decisions, each require a formidable multidisciplinary effort and mark a significant deviation from current standard practices in management. This change places a heavy burden on scientists to produce policy relevant information and to communicate this information to decision makers in a format which is useful to them. The science-management gulf and the requirement for improved scientific communication are well known issues. Inability to communicate policy relevant information is a charge frequently directed against scientists (Barker, 2006; Caplan, 2006; Roux et al., 2006). In particular, understanding the spatial and temporal constraints to management imposed by the nature of ecosystems themselves is of paramount importance in management and often an area where environmental science is remiss (Roux et al, 2006).

A key challenge for scientists therefore, is the *synthesis* of information on the relevant space and time scales from both ecological and social sciences and *effective communication* of this and other relevant information to decision makers (Dennison et al., 2007).

In the European Union a requirement to implement the EA in Europe's four regional seas (Baltic, Black, Atlantic and Mediterranean) is enshrined in the Marine Strategy Framework Directive (MSFD). The directive specifies 11 criteria (descriptors) for which Good Environmental Status (GEnS) must be achieved by 2020. The implementation of the EA in each of the four regional seas poses an immense challenge, due to the complexity of the ecosystems themselves and the competing interests of individual nations with their own unique cultures, languages, traditions and governance structures. While there is a vast body of scientific knowledge pertinent to the management of these seas, communicating the relevant information, uncertainty and complexity in a means that is policy-relevant, rapidly accessible and digestible to the decision maker (with little time and a superficial knowledge of the seas) is a major challenge to effective implementation of the MSFD. The information required for informed decision making comes from several different disciplines: ecosystem information from ecologists, social and economic data from economists (two disciplines with their own well documented communications problems) and data on integration of policy and existing governance structures from the social sciences.

One widely accepted framework for the analysis of environmental problems and sustainable development is the Driver, Pressure, State, Impact, Response (DPSIR) approach (Borja 2006). The KnowSeas project has adopted a modified version of this conceptual model where the term "Impact" is replaced with the term "Welfare", to avoid confusion between environmental and economic impacts. The DPSWR components encompass both human and ecological elements of social-ecological systems: Drivers are considered to be the economic and social forces that result from government policies, markets and the activities of private industry. Pressures are the ways these drivers place demands upon ecosystem services (irrespective of whether

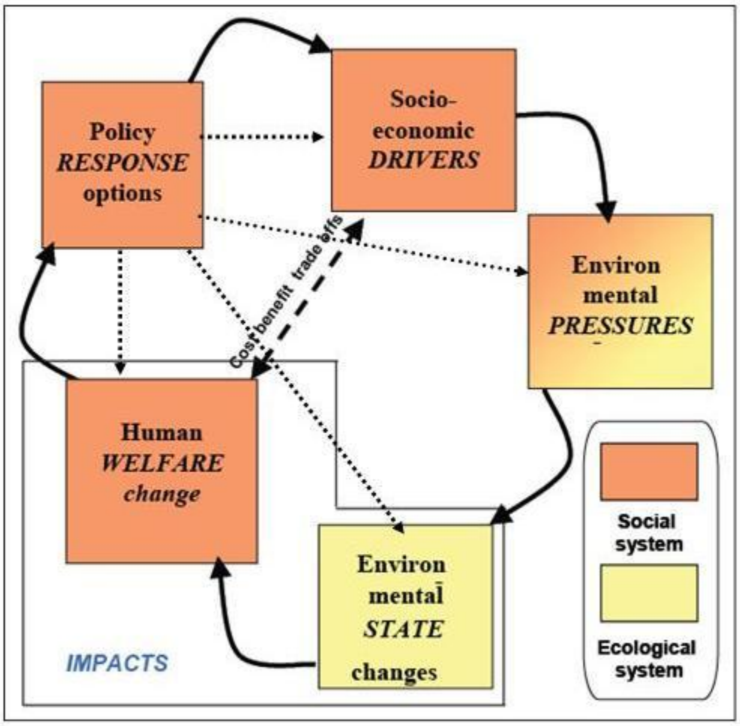

Figure 1: The DPSWR approach indicating the social and ecological parts of the system as well as the trade-offs between economic drivers and environmental human welfare changes.

these demands can be met in a sustainable manner). These demands are the interface between the social and ecological components of the system. State changes are the changes in the ecosystem resulting from the pressures (i.e. ecosystem impacts) and these in turn can result in changes to human Welfare (often leading to social and economic impacts). The Response to a particular problem may be directed towards any of the other elements (D, P, S or W) in an effort to achieve a balance between the benefits of economic and social development and the ecosystem costs, usually determined by real or potential changes to human welfare. Figure 1 shows the DPSWR management cycle, indicating the social and ecological components of the system.

The DPSWR approach provides a useful basis for systematic analysis to understand scale mismatches in social ecological systems. Each element of DPSWR has associated space and time scales. For example, an invasion by an opportunistic species may cause a major State change at the sub-regional level and affect human Welfare by altering fisheries and aquaculture, damaging recreation, affecting human health (e.g. by introducing toxic species) and diminishing the non use value of biodiversity and habitats. This may be the result of Pressure from ballast water discharges from ships operating across regional or even global scales as a consequence of national, regional and global shipping policy, practices and markets. A Global Ballast Water Convention has already been negotiated though it is not yet in force. This is largely due to concerns about the practicalities and costs of measures that must be taken at geographical scales much larger than the subregional and local scales in which the State and Welfare changes are felt. In many cases, countries and the national and transnational shipping industries are unwilling to act because of limited scientific and technical information and the need to ensure that costs are apportioned fairly and that measures are in place to avoid ‘free riding’ by those unwilling to comply.

Each of the boxes in the DPSWR model contains a complexity of elements and processes that operate on different temporal scales. There is no clear pattern of temporal scale characterising each box except perhaps for Responses which - in the absence of existing governance structures and policy - tend to occur in the range of years to decades. Drivers also tend to change quite slowly (except in the case of sudden market shocks and failure) and may be ‘locked in’ to broader issues of demography, major economic strategies, fixed infrastructure development and global markets. This is one reason why sustainable development is so difficult to achieve because it often involves changing the nature of the drivers, some of which may only be profitable because they are free riding the environmental economy and depleting natural capital. Given these difficulties, policy responses often focus on alleviating Pressures (for example by waste treatment plants or changes in fishing technology), attempting to improve ecosystem State by protecting or building resilience (e.g. by marine protected areas), or by supporting Welfare by compensating for loss. The relationship between Pressures, State changes and Welfare changes occur across a wide range of timescales from catastrophic change (e.g. the release of toxic mine tailings) to change over decades (e.g. the build up of eutrophication or gradual loss of species and habitats). Governance systems tend to be more responsive to rapid changes than those of a gradual but often more pernicious nature.

Understanding scale mismatches is essential for effective decision making. Figure 2 illustrates a matrix of the time and space scales relevant to ecosystem processes and to decision makers. In theory any environmental problem can fit into such a matrix to occupy a "decision space" for effective management. In practice placing the DPSWR elements within this matrix is not a trivial exercise and requires a careful and systematic approach.

	Terrestrial	Local inshore	National EEZ	Trans-boundary	Regional Seas	EU Wide	Global
Within one year							
Within 1 political term (5 yrs)							
Before 2020 (Target for GEnS)							
By 2050							

Figure 2: Matrix of time and space scales. The grey area represents the area initially accessible by the MSFD (Marine Strategy Framework Directive). The heavily outlined box focuses on National EEZs. Transboundary is defined as involving neighbouring countries (but not necessarily Member States). The area shaded with horizontal stripes represents that covered by the Water Framework Directive, already fully in place and overlapping in inshore coastal waters.

Effective social ecological governance needs to work at a scale that will influence the balance between the societal benefits of the social and economic Drivers and their ecological costs (expressed in terms of Welfare in the DPSWR model). We argue that to be effective, this must encompass the whole social ecological system for any particular issue. According to Cumming et al. (2006) a scale mismatch in socio-ecological systems occurs when the scale of natural environmental variation on the one hand, and the scale of management (institutions, rules etc.) on the other hand are aligned in such a way that functions of the social-ecological system are disrupted or lost, i.e. deterioration of the ecological system, the social system or both occur.

Spatial scale mismatches may arise when social institutions work at too broad a scale to deal with issues that may be focussed on a particular local area ("one law fits all", whereas diversity in conditions would require locally adapted management). Failure to deal with local issues (such as habitat loss) may eventually have cumulative effects at a larger scale. Alternatively, they may arise when no institutions are available to manage broad-scale issues or can only work at a scale that allows partial solutions, leaving the overall problem unmanaged (e.g. the decline of populations that send a considerable part of their lifecycles outside EU waters). Temporal scale mismatches arise when decision processes or institutional changes are too slow to match fast dynamics in the ecological system, or when management decisions lack consistency to manage slow ecological processes. Finally, organizational scale mismatches arise when the hierarchy of social institutions or processes is not aligned with the hierarchy of natural processes, leading to a lack of institutions that can respond to broad-scale ecological processes, or governance levels that interfere with each other, essentially trying to manage the same ecological phenomena at different hierarchical (social) levels.

Decision Space Analysis (DSA) is a tool for visualising scale mismatches and communicating them more effectively to decision makers. It also provides a platform for integrating the research outputs of the KnowSeas project. The purpose of the tool is to overcome the science-policy gap through novel and effective communication techniques. Treated academically, the issue of scale mismatches may appear to be highly theoretical (e.g. Cumming et al. 2006). A more practical means of communicating these important concepts is by illustrating concrete examples of spatial and temporal mismatches of the DPSWR elements for a particular problem in a regional sea. Given the uncertainty associated with ecosystem change and the complexity of possible responses of an ecosystem to changing pressures, effective ecosystem based management requires communication of spatial and temporal scale mismatches with sufficient detail to be useful but sufficient simplification to be readily and rapidly understandable. Scientific information for policy makers should be unambiguous, not overly complex, and compatible with existing planning methods (Westley, 1995).

In this paper we provide a framework for the synthesis and communication of KnowSeas scientific outputs and develop a basis for graphical presentation of multidisciplinary data pertinent to scale mismatches. The purpose of the document is twofold:

1. To develop a tool for graphical synthesis and communication of scale mismatches in social ecological systems.

2. To focus KnowSeas research so that all elements of the project provide coherent and practical scientific outputs.

This will allow project participants to focus their research findings toward practical applications as well as support the integration of the different project Work Packages. In this document we use the interlinked problems of eutrophication and Cod fisheries in the Baltic Sea as an illustrative example for DSA. More detailed analyses of the implications of the MSFD in the Baltic and its relationship to the cod and eutrophication have been published elsewhere (Roth & O'Higgins, 2010; O'Higgins & Roth 2011 in press). This case study is a representative example and the general template developed here will be used for all the KnowSeas case studies. However individual cases will have different characteristics and the overall layout and format of the product should remain flexible to incorporate case study differences. In other words the example given below is intended to be indicative rather than proscriptive.

2. ELEMENTS AND DESIGN OF DECISION SPACE ANALYSIS

Decision Space Analysis (DSA) brings together information from many sources to communicate the general context and specific details of a particular issue and contains several different elements reflecting aspects of the problem to be analysed. The target audience for the DSA is the interested decision maker, assumed to have a higher education but little knowledge of the particular issue and with little time to spend on each aspect of the issue in detail. Important characteristics therefore of the DSA are that it has strong visual impact, that it is logically and coherently presented and that the information contained within it may be absorbed rapidly by the target audience.

Clear presentation and visual impact of the DSA are paramount in achieving this rapid visual communication. The elements of the DSA were compiled and presented using Adobe Illustrator graphic design software. The physical shape and size of the printed DSA is based on the well known and easily recognisable standard National Geographic map (80cm x 51cm) (see Wood and Fels, 2008 for a thorough treatment of the impact of the physical qualities of the map) and graphically the page is laid out according to the "golden ratio" for visual appeal (Figure 3).

There are two background colours. Quantitative information about the spatial and temporal scales of phenomena pertaining to the Baltic Sea ecosystem are contained in the main body of the page with the light blue background and components include:

1. Timeline
2. Decision Space Maps
3. GEnS rosette diagrams
4. Trajectories of parameters required to achieve GEnS
5. Space Time diagrams for DPSWR elements

The information presented in the dark blue segment of the page contains general context through several elements:

6. A conceptual diagram
7. Summary pie charts
8. A cartogram
9. Rapid Policy Network Mapping results

For the purposes of KnowSeas, all case studies focus specifically on implementation of the MSFD, they share common deadlines and a common goal of achieving GEnS. This means that some elements in the DSA are common to all case studies. For example the timeline for implementation and the descriptors for Good Environmental Status (target environmental states) will be common to all DSAs in KnowSeas. In the following sections each of the elements listed above are described in more detail.

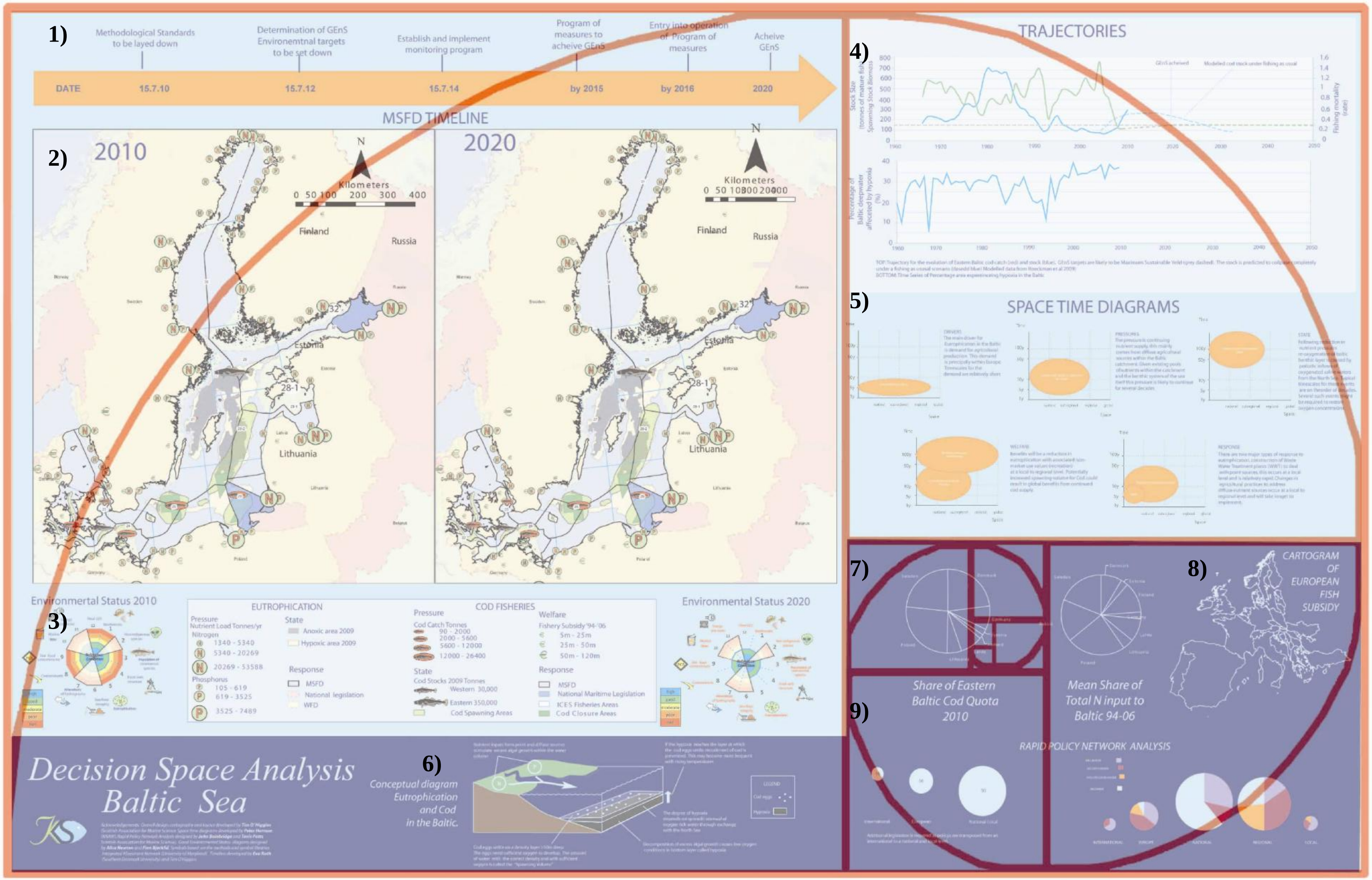

Figure 3: Layout of DSA showing the Golden Ratio (see text for description of numbered elements).

2.1 Timeline

Figure 4: Simplified version of the MSFD timeline.

The timeline was developed through document analysis of the MSFD (EU 2008). All references to time were extracted and the version presented above (Figure 4) is simplified showing only the scientific milestones. A full version showing the procedures required of the Commission, the member states and the regional institutions has been published elsewhere (Roth & O'Higgins, 2010). The timeline allows for rapid determination of the deadlines for each member state under the directive, which can be compared with the trajectories required to reach GEnS (see section 2.4).

2.2 Decision Space Maps

Maps provide an excellent means of rapidly communicating a large amount of pertinent information to the decision maker. Maps are also excellent communication tools for several reasons. First, maps are a cultural and cognitive universal (Blaut, 2003) and reading maps appears to be an innate ability in human beings. Second, in the context of European decision making, maps are not heavily dependent on language; they do not require linguistic translation. Third, maps require a type of active reading (Wood & Fels, 2008). Unlike written communication where the vehicle for transmission of information is a precomposed alphabet already residing in the readers mind, in maps, the symbol language is new so the reader must actively engage in understanding the map, and this process reinforces the message of the map itself. Fourth, maps can be used to collate many different types of information.

Decision Space maps are cartographically unusual in that they collate information typically not aggregated within a single map. In contrast to standard political or physical maps, the Decision Space maps communicate the political, physical, chemical, biological, social and economic data required to address a particular problem together in the same place. This is illustrated in our Baltic case study. In this case the DPSWR elements for eutrophication and for cod fisheries are treated separately (Figure 5).

For cod the major pressure is catch (symbolised by the cod image in the red oval). The size of the symbol is scaled based on the most recently available catch data for each of the ICES statistical areas (ICES 2010). Similarly the state of the cod stocks (symbolised by the cod image) is taken from the most recent ICES data (ICES 2010); the stocks are assessed for the eastern and western areas separately hence there are two symbols on the map. In the present version of the Baltic DSA, total EU fishery subsidy (under the CFP) is used as a proxy for the welfare loss generated by the fishery. Data are based at the NUTS III level (EU nomenclature of territorial units for statistics) and are derived from an online database of EU fishery subsidy (http://fishsubsidy.org). A more complete picture of welfare generated by fisheries will be derived from an existing study on regional levels of fisheries dependency (Goulding et al. 2000), this will require spatial rendering of data already held by the KnowSeas project. The potential for response is mapped according to the jurisdiction of legislative instruments. For the MSFD (the member state EEZs are shown as light blue areas delineated by black), areas under national legislation of non-EU nations (where the MSFD does not apply) are shown in darker blue. Current cod closure areas are shown in dark green.

For eutrophication the main pressures are nutrient inputs. The symbols (red letters N and P) are scaled according to measured riverine nutrient loads using data from the geospatial portal of HELCOM (http://maps.helcom.fi/website/DataDelivery/viewer.htm). Eutrophication State is illustrated by the extent of anoxia and hypoxia in 2009 (georeferenced from Hansson et al. 2009). Welfare is not represented under eutrophication, as no data with adequate spatial resolution concerning the welfare effects of eutrophication in the Baltic are available, currently such data exist only at the national level (Söderquist, 2000). Responses are mapped as legislative areas and management boundaries. As with the cod example, potential for response is mapped according to the legislative jurisdiction. The Water Framework Directive is delineated in red (filled with yellow on land and light green in coastal waters) and areas under national legislation are shown light pink.

Maps are arguments (Wood & Fels, 2008) and each element of a map contributes to the argument. The emphasis of the map is controlled by cartographic techniques and use of colours and size of symbol can each be used to emphasize different elements. In the decision space map the goal is to present the DPSWR elements with equal weight, set in the spatial context of relevance, in this case the Baltic catchment.

The bold colours used for the quantitative symbols for pressures and states and potential response instruments in the marine environment contrast with the more muted tones used for the terrestrial areas and serve to focus attention on the marine area and its management problems.

Symbols in the maps are based on those developed by the University of Maryland Integration and Application Network (http://ian.umces.edu/symbols/) and are created using Adobe Illustrator.

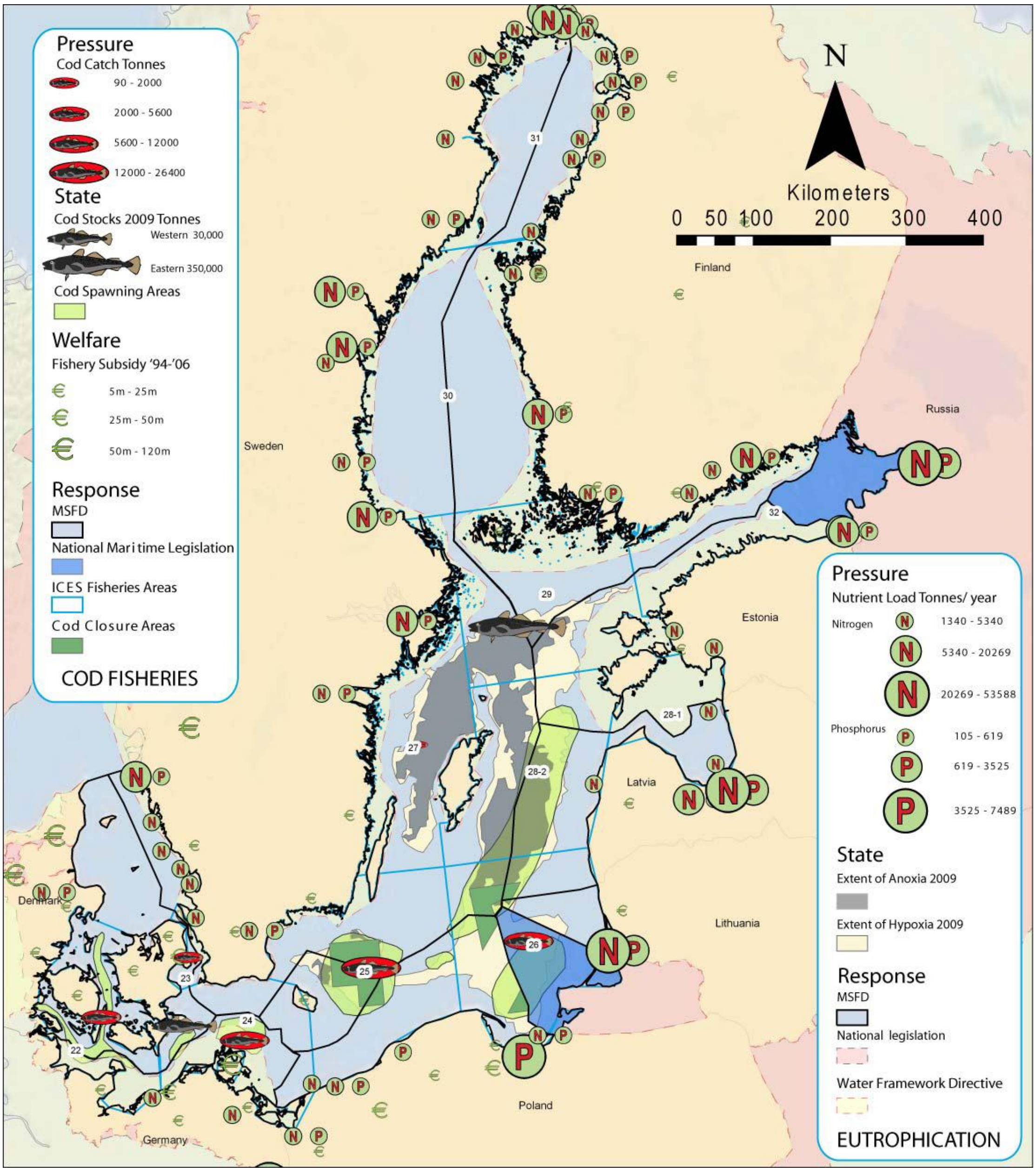

Figure 5: Example of a decision space map showing current DPSWR elements in the Baltic Sea for eutrophication and cod fisheries.

a)

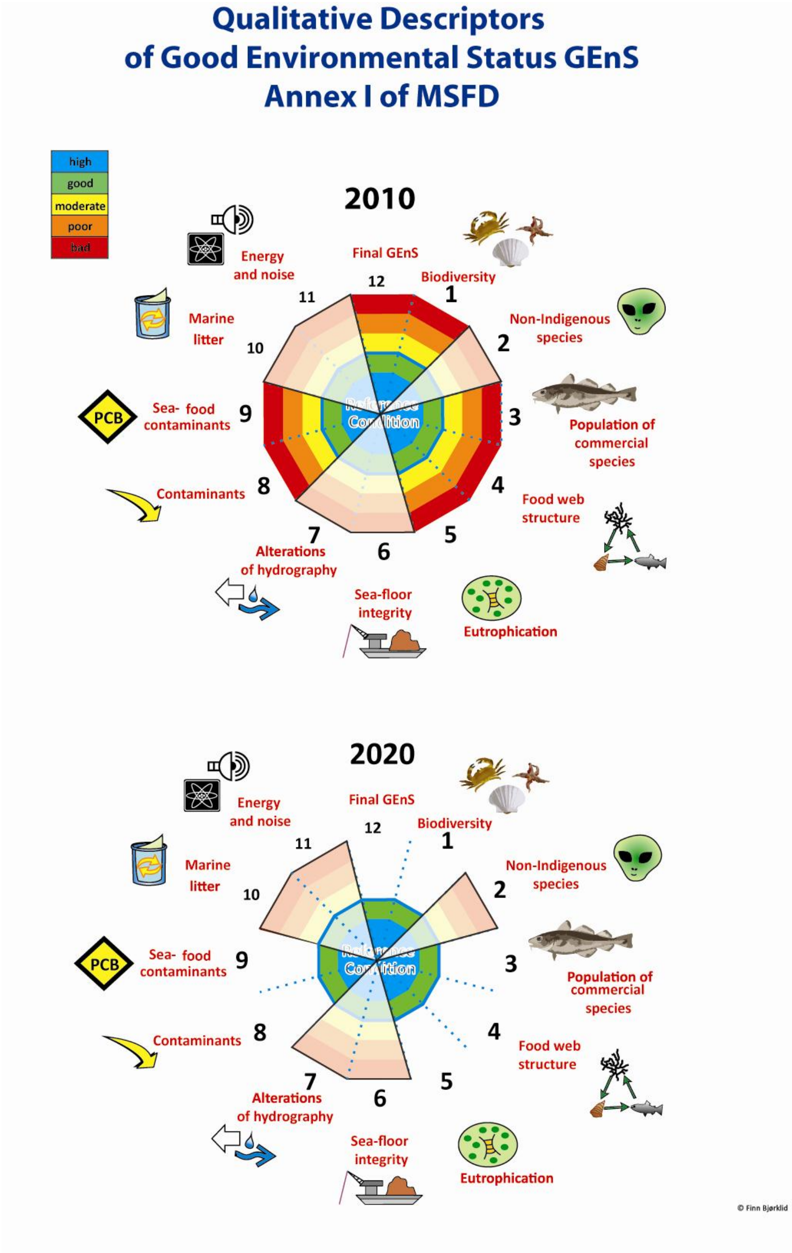

Figure 6: Rosette diagram of GEnS relevant to eutrophication and fisheries in the Baltic case study a) assumed current Environmental Status b) Target status under the MSFD.

2.3 Rosette Diagrams

The Rosette diagrams above (Figure 6) summarise the environmental status (aspects of environmental State) for each of the eleven indicators of GEnS listed in Annex 1 of

the MSFD and are symbolised using symbol libraries provided by the Integration and Application Network (http://ian.umces.edu/symbols/). The symbols have been developed to facilitate science communication with decision makers and actors.
Each Segment of the rosette diagram represents a different desciptor and these are summed to provide the 12th segment “Final GEnS”.

The rosette concept is based on Rockström et al., 2009, and incorporates the precautionary principle. Each section of the rosette has its own scale, appropriate for the individual descriptor, and which might already be an integration of various indicators for that particular descriptor. The desired “target state" is in the middle of the rosette and represent the reference condition for Good Environmental Status. Deviations for this are shown as a "pie section”, which grows in area to represent a growing deviation from the reference state. The examples in the figure are for "Cod Fisheries" and "Eutrophication in the Baltic".

Not all indicators are relevant to all issues in all areas, and the rosette diagram provides a means of displaying which indicators are being addressed as well as illustrating changes in environmental status over time.

In the case of the Baltic eutrophication and cod fisheries, seven of the eleven indicators are directly relevant (O’Higgins & Roth, 2011) and the remaining indicators are left visible but shaded. The first figure (6a) shows the assumed current status in 2010 with all indicators having bad status. The official environmental status of these indicators will only be established when the status and targets for GEnS are agreed (by July 2012, see timeline Figure 4).

2.4 Trajectories

In order to achieve GEnS, the indicators specified within the Directive will need to achieve the targets to be set out by each member state in July 2012. The ability to achieve specific targets is determined both by the remediation measures put in place i.e. Response (which in terms of the MSFD are bounded by areas under European jurisdiction) as well as the timescales inherent to the particular system in question.

Figure 7a shows a time series of historical data for cod stock size and fishing mortality (ICES data) along with a projected future trajectory of stock size under a fishing as usual scenario (redrawn from Röckmann et al., 2009). The dashed grey line indicates Maximum Sustainable Yield which is the proposed indicator of GEnS (EU 2010). This trajectory shows that a gradual increase in fishing pressure over the next decade may achieve GEnS but that this might not ensure the persistence of the Eastern Baltic cod stock over time.

Figure 7b illustrates the time series of the area of Baltic deepwater affected by hypoxia. Though targets have not yet been set for the areal reduction in hypoxia, attempts at alleviating nutrient pressures have shown little effect on eutrophication (Elmgren 2001; Artioli et al. 2008) and intensification of farming techniques in newly acceded EU states may increase in the near future (Humborg et al., 2007). However existing loads of nutrients within the bottom layers of the water column and within the watershed mean that excess nutrient supply and eutrophication are likely to continue

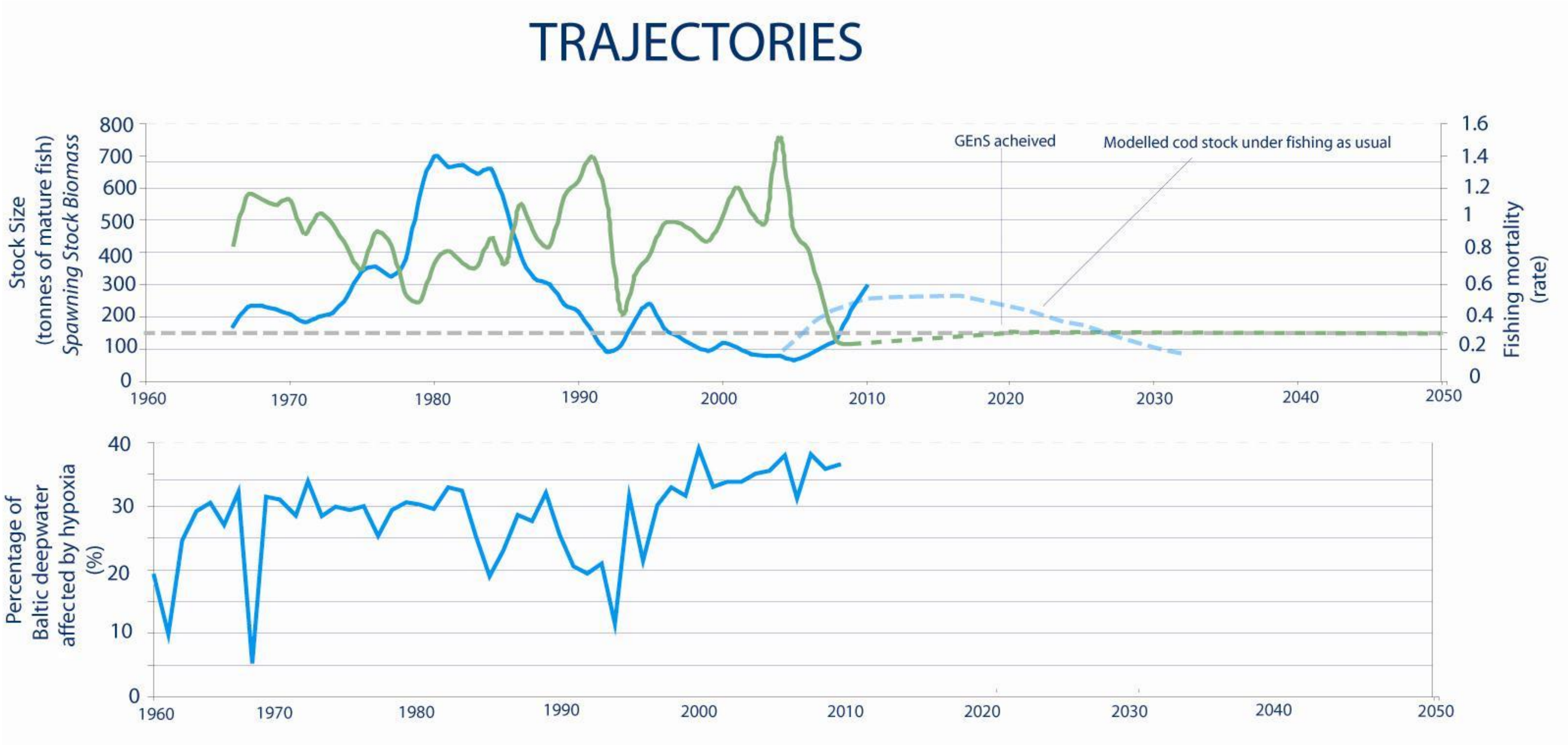

Figure 7:a) Trajectory for the evolution of Eastern Baltic cod catch (green) and stock (blue). GEnS targets are likely to be MSY (dashed grey). The stock is predicted to collapse completely under a fishing as usual scenario (dashed blue).
b) Time series of percentage area experiencing hypoxia in the Baltic.

for at least 30 years (Neumann, 2007). Realistic targets by 2020 must therefore take these "locked in" processes into account.

2.5 Space Time Diagrams

For many issues the time and space scales of the DPSWR elements vary widely from global to local and from annual to very long timescales. Under such conditions, mapping the physical location of the pressures (as in the Decision Space maps) is not necessarily useful. For the decision maker, simply knowing that a particular Driver is for example global is more useful than seeing a map of its distribution. Similarly for many phenomena (e.g. eutrophication in the Baltic) the exact timescales for recovery are known to be very long, but their exact length is not known. In such cases space time diagrams can provide the general spatial and temporal context of the particular issues.

A detailed methodology to elucidate spatial and temporal scales of relevance has been developed as part of KnowSeas WP3 (Gilbert et al., 2010; Herman et al., in preparation). This analysis has identified 8 major steps in the process:

1. List the important drivers, pressures, state changes, welfare impacts and societal responses for the case study. This list is based on literature, reports, expert knowledge and analysis of the problem. A useful procedure is to start from one element of the list (e.g. historically recorded state changes in the natural system) and work back to the forces that caused these changes, and forward to the implications and the societal feedback started from these changes. This strategy was used in the European Lifestyles Marine Ecosystems project (Langmead et al., 2007)
2. Document these elements narratively, in order to identify the important parameters describing their dynamics. In particular, typical rates of change are important for temporal scale. Extent and grain of the spatial patterns matter, as well as the strength of spatial gradients when viewing the system with different grain (is the phenomenon spatially variable at very small scales and relatively homogeneous at coarse scales, or rather variable at broad scales but very predictable at small scales, or other combinations?).
3. Identify how important parameters can be deduced from existing data sets or analyses. Identify gaps in knowledge or possibilities for further analysis. Validate the narrative as much as possible with existing studies.
4. Use the parameters of the processes to estimate spatial and temporal 'typical' scales. Useful questions for this analysis are, for temporal scales: at what time scale will the system return to equilibrium after a disturbance? How fast can a change of policy be implemented? How long is a certain pressure expected to remain stable? How fast can a driver change? Also, for spatial scales, relevant questions are: at what distances is the pattern or process strongly autocorrelated (such that it will be approximately the same over this distance); at what distances do we see highest variation; what is the extent (total range) of the phenomenon; if processes are variable at one scale and predictable at another, can they be split into a useful hierarchy with different levels operating at different scales?

Typical scales have to be derived from these considerations. Almost certainly, expert knowledge will have to be used to fill in gaps, but explicit analyses of data that corroborate the statements are better.

5. Map as many patterns as possible in explicit spatial maps. Adapt the maps to properly show the grain and extent (include insets at higher resolution to show the grain faithfully if needed)
6. Make space-time diagrams of processes based on the above analysis. Indicate useful reference scales on the space and time axes. For the KnowSeas project, agreed-upon typical scales are for time: 1 year, 5 year (one political term?), 10 year, 40 year (by 2050); for space: national EEZ, subregional sea (e.g. North Sea), regional sea (e.g. N.E. Atlantic), global
7. Compare scales, as reflected in the maps and the space-time diagrams, of the different elements of the DPSWR model. Elucidate and discuss scale mismatches.
8. Investigate possible future scenarios that could resolve the scale mismatches, either by adapting pressures or adapting the institutional framework in the responses. Discuss where improvements can be made.

Space time diagrams for the DPSWR elements for eutrophication in the Baltic are shown in Figure 8. The diagrams allow rapid understanding of the vastly different time and space scales for different aspects of the system. Note, for Welfare, that the costs of changing agricultural practices are borne in the short to medium term at a regional and subregional level while the benefits (of improved water quality and increased fish biomass) occur at larger time and space scales. Note also that the installation of Waste Water Treatment is the only aspect of the problem that is feasible within the timescales of a political term if verifiable reductions in pressure are required in the same time period. This has frequently made it the preferred technical measure but, in the longer term, it may be neither the most sustainable nor the most cost effective one.

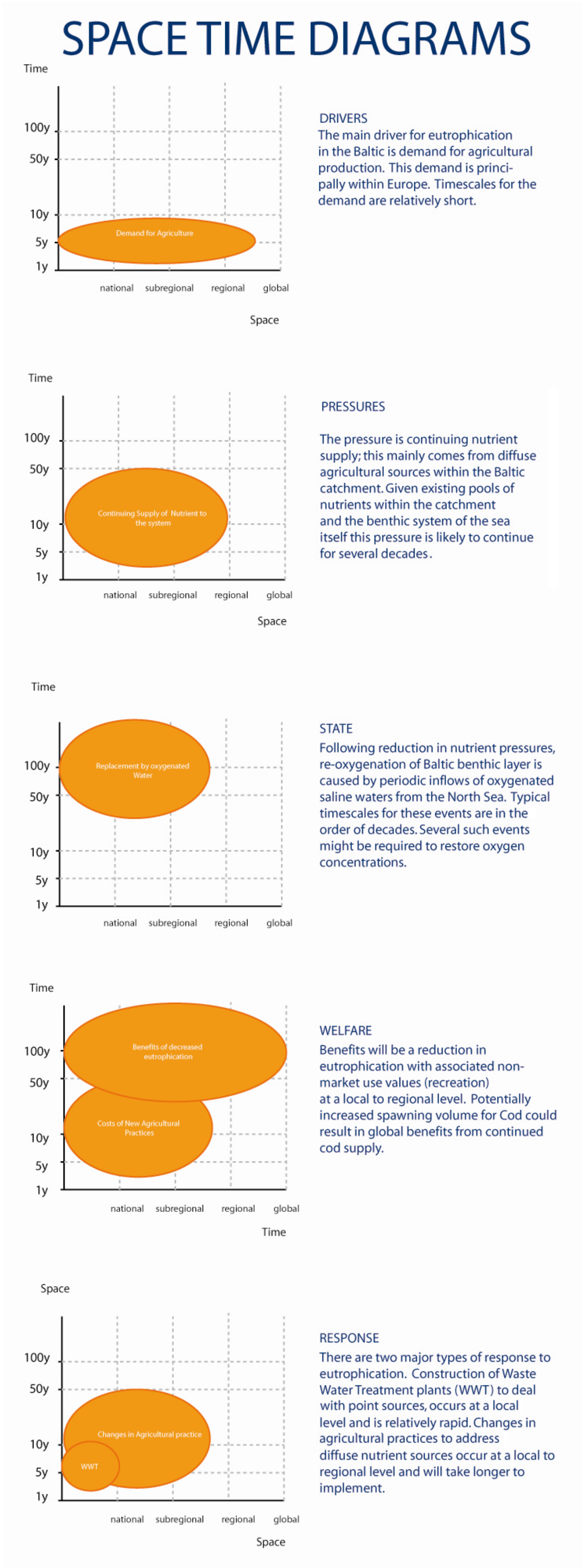

Figure 8: Space time diagrams for eutrophication in the Baltic.

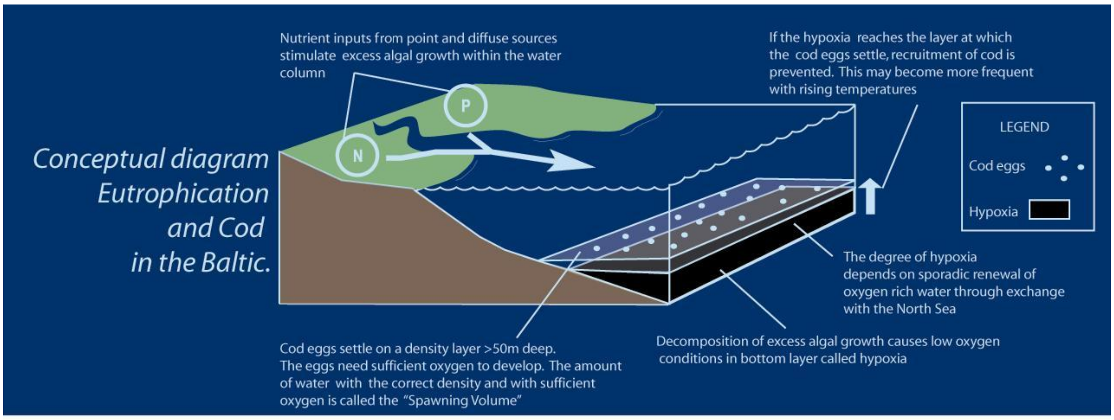

Figure 9: Conceptual diagram showing the relationship between hypoxic waters and cod egg location. Note the information presented is greatly simplified in comparison with technical information found in scientific journal articles on the topic.

2.6 Conceptual Diagrams

Conceptual diagrams are a well tested and useful tool for the communication of environmental information to those with non-scientific backgrounds (Heemskerk et al., 2003; Dennison et al., 2007; Bricker et al., 2007). These may be used to communicate qualitatively the essential details of a particular system but are not required to be quantitative or to give a comprehensive account of the available information. Conceptual diagrams were developed using Adobe Illustrator and utilised the existing symbol libraries developed by the University of Maryland's Integration and Application Network: http://ian.umces.edu/symbols/

Understanding the intricate physical, chemical or biological minutiae of environmental systems is the stock and trade of scientists but this level of detail is not necessarily helpful to managers. However, as a first step, understanding the essential mechanisms controlling a particular environmental problem is essential in order to make informed decisions.

Figure 9 summarises the main aspects of the relationship between eutrophication and cod spawning in the Baltic. The diagram allows us to rapidly understand the general functioning of the systems and includes nutrient inputs, eutrophication and hypoxia as well as the concept of spawning volume.

2.7 Rapid Policy Network Mapping

a)

b)

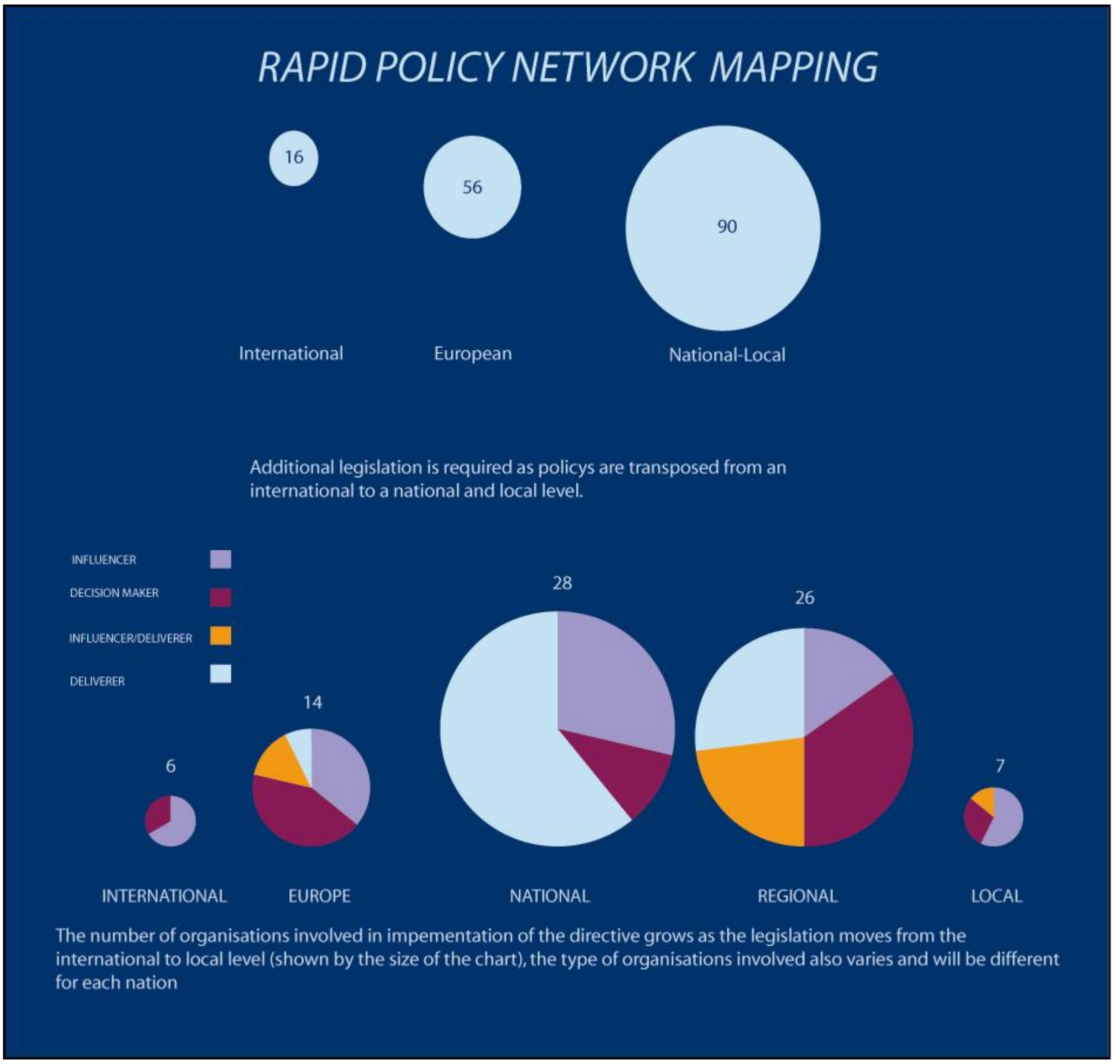

Figure 10: Rapid Policy Network Mapping results. a) Volume of legislation as MSFD is transposed. b) Number of institutions involved in implementation at different spatial scales. Both examples are for the UK.

Effective implementation of environmental policy is dependent on the efficiency of the governance structure. For individual nations to achieve an ecosystem approach through implementation of the MSFD, the directive needs to be transposed to national laws and these, in turn, to local laws. The manner in which this is done varies nation by nation, and the number of agencies and individuals involved in implementing the directive also varies. Given "institutional inertia", understanding the governance system, its size and complexity can help decision makers understand the feasibility of particular plans or targets.

Rapid Policy Network Mapping (RPNM) adopts the 'snowball method' of policy network analysis (Bainbrige et al. in prep). Data on policy actors and instruments is collated using a '*focussed synthesis*' approach (Majchrzak,1984) which uses sources including peer reviewed articles, governmental websites, policy and legislative instruments and planning documents. It applies the findings of this research process to templated 'maps' using Cmap Tool freeware allowing open source access (Institute of Human and Machine Cognition, 2010).

Analysis was initiated by first examining documents from the Scottish Government, the Department for Environment, Food and Rural Affairs and the UK Environment Agency. Based on referrals and citations, information on subsequent actors and instruments was simultaneously captured and analysed until no new relationships relevant to the two directives was uncovered.

Policy Actors are categorised as Deliverers, Influencers and/or Decision Makers/'Owners'[1] and, where relevant, are linked to other actors, events or activities in the policy lifecycle within and between policy domains. Policy Instruments are categorised by policy domain with relationships and dependencies recorded.

Two metrics from Rapid Policy Network Mapping (RPNM) are shown in Figure 10. These results come from an analysis of the MSFD in England and Scotland (Bainbridge et al, in prep). Figure 10a shows the increasing amount of legislation required as policy is passed from the International to local level and Figure 10b shows the number and type of institutions involved in the same process.

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[1]**Definitions of various types of actor from Bainbridge et al. (in prep)**

Deliverer: An entity which is required, invited or obliged to be involved in the official policy development process. They can affect the outcome of the policy process based on their delivery of actions, processes or reporting which facilitate the interpretation, transposition and/or implementation of the policy. They cannot, in principle, affect the outcome of the policy process based on their opinions and views.

Influencer: An entity involved in the official policy development process. This does not including entities responding to a public consultation process, or similar, if they are not legally, morally or practically required, invited or obliged to be engaged in the official policy development process. It is assumed that Influencers can affect the outcome of the policy process using legitimate means based on their opinions and views.

Owner/Decision maker: An entity which has the authority to make a *decision* which can affect the policy outcome as concerns intellectual or practical components or which *owns* all, or component parts, of the policy development process within a specified boundary. The majority of these actors are responsible and accountable for the successful delivery of intellectual and/or practical objectives which may include reporting, data, legislation etc. For example the UK Secretary of State for the Environment is the authority responsible for delivering Good Environmental Status in all UK marine waters and is accountable to the European Commission for *delivering* this within agreed timeframes and for providing the necessary proofs of progress. Decisions may be made by Owner/Decision Maker's following consultation and/or negotiation however it is assumed they have the ultimate authority to decide outcomes.

2.8 Summary Pie Charts

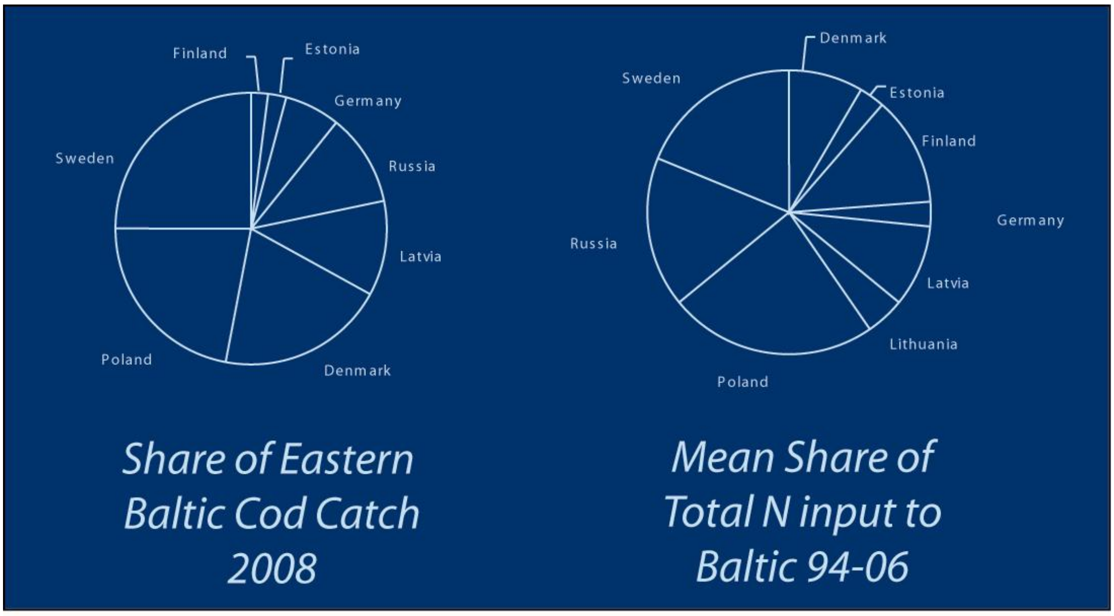

Figure 11: Pie charts showing Baltic cod catch and riverine nitrogen inputs by nation.

Any relevant statistical figures can be displayed as pie charts or other familiar means of graphic representation. While actual numbers do not need to be displayed, the pie charts give an immediate idea of the likely degree of interest in the issue. For example, Figure 11 indicates that while Russia is a relatively minor player in the total cod catch, it has a major share of the Total N input to the Baltic. The specific location of nutrient input in the Baltic is also important to consider. For example most inputs from Russia (not under the MSFD) would affect the Gulf of Finland but not the Bay of Bothnia or the Kattegat.

2.9 Cartograms

A cartogram is a representation of statistical data in geographical distribution on a map, where the elements of the map are scaled according to the statistical data rather than their actual area. Figure 12 shows a cartogram of EU fishery subsidy. The data come from http://fishsubsidy.org. The cartogram was generated in ArcGIS 9.3 using a diffusion based method (Gastner & Newman, 2004). The role of the cartogram within the Baltic example of the DSA is to give a continent wide perspective on the relative size of the fishery subsidy in each nation; this gives a broader context to the issue in the particular regional sea.

In order for a cartogram to be visually effective the shape of the countries must be easily recognisable, thus the cartogram relies on prior visual recognition of the shape of the map. Therefore, for the purpose of DSA, cartograms are useful for displaying information at the European scale and at the scale of subnational difference (i.e. within a particular country). Cartograms are not effective at the intermediate scale such as those of the basins of Europe’s regional seas since the shape of the basins of any Europe’s regional seas is not instantly recognisable.

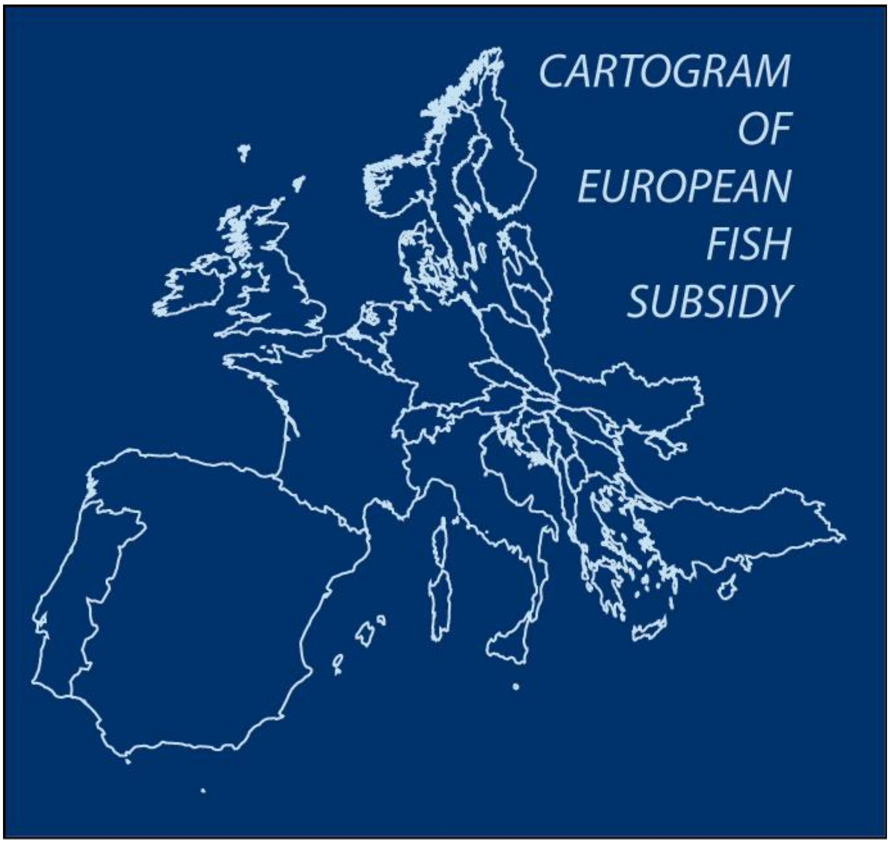

Figure 12: Cartogram illustrating the distribution of EU fisheries subsidies within Europe.

3. DISCUSSION

As attempts to implement the Ecosystem Approach gain momentum, increasing numbers of examples of spatial and temporal scale mismatches in social-ecological systems are emerging (Pelosi, 2010). Given that sustainable social systems are reliant entirely on the ecological systems in which they are contained (Boumans, 2002) and that the mechanisms driving the development of social systems differ from the evolutionary mechanisms which generate ecological systems, scale mismatches may be seen as symptoms of social-ecological systems in disharmony (and perhaps as indicators of unsustainability). Having said this, it is also important to point out that system scale appears to be increasing as a result of globalisation and this is making it difficult to sustainably manage systems at small geographical scales through such paradigms as Integrated Coast Zone Management (Mee, 2010). Effective implementation of an Ecosystem Approach must therefore recognise and confront such scale mismatches.

Recognition and understanding of scale mismatches by decision makers is the first step towards realignment of the scales. Informed decision making is dependent on understanding the outputs of scientific research, and continuing decline in ecosystem service provision as well as the outlook for future global ecosystems (MEA, 2005) is evidence in itself for the inefficacy of science in informing environmental policy. Decline in environmental quality can thus be viewed partially as a failure on the part of environmental scientists to communicate the appropriate information to decision makers.

This communication gap may be associated with the professional rewards system in academia. Academic accolades and financial success are obtained based on the metrics of peer review rather than on the practical outcomes of their science (Merton, 1968). Thus it is in the scientists' own self interest to communicate to other scientists through technical literature rather than to produce information which is directly digestible by decision makers.

Decision Space Analysis is an attempt to overcome this communications barrier through provision of relevant information in an accessible format. We have developed a number of elements which graphically convey the spatial and temporal characteristics of the DPSWR for a given system. These elements combine research outputs from several different fields and attempt to provide a rounded and comprehensive picture of the information required to make decisions. In particular the collation of multidisciplinary data within maps and clear and simple depiction of the spatial distribution of DPSWR elements mark a real step towards effective communication. The visual appeal of the DSA is also of importance; it might be a truism in most disciplines but for environmental scientists it is important to realise that "the medium is the message" (McLuhan, 1964).

The elements of the DSA may be used together as presented here or separately, and the Decision Space maps presented in this text have already been interfaced with the GIS Seas tool (See KnowSeas Deliverable 6.2 for details of construction and development of the GIS Seas tool) and are available in kml format on the KnowSeas website at http://www.knowseas.com/database/gis-seas

By applying DSA to each of the KnowSeas case studies a symbol library will be developed. This library will be composed of all the symbols used and will be a valuable resource for further communication and development of conceptual models for European implementation of the Ecosystem Approach.

The example presented above is focused specifically on Baltic cod and eutrophication in the context of the EU MSFD and the template developed will be applied to each of the KnowSeas case studies, however the techniques employed and general layout are suited to any application of the Ecosystem Approach. The Baltic Decision Space map for 2020 illustrating GEnS cannot be accurately completed until the actual targets for the relevant descriptors are known. Similarly, the trajectories shown for cod and hypoxia may need further refinement and further expert input from the case study work packages. The example used here for RPNA comes from the UK, but in the final version of the Baltic DSA this information will be based on information from Baltic nations. Choice of trajectories and models must be reliable, and a range of results should be displayed in the trajectories to communicate the uncertainty and difference of scientific opinion. The full research outputs of KnowSeas are not due to be completed for another two years and the final contents of the DSA will include both the targets for GEnS and additional KnowSeas research outputs as they develop.

Nevertheless, the template marks an important step towards integration and communication of the data required to implement the Marine Strategy Framework Directive and to understand the spatial and temporal mismatches which can obstruct the process.

Given that the DSA is a work in progress, we would welcome comments and suggestions on how to improve its content and presentation. We will revise and update the current document periodically as the DSA is refined and new information gathered and interpreted.

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