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Model instruments for marine biodiversity policy

A quick scan

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Wettelijke Onderzoekstaken Natuur & Milieu

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Model instruments for marine biodiversity policy

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Abstract
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The Netherlands Envrionmental Assessment Agency (PBL) developed several biodiversity models for the terrestrial environment to support policy making and evaluation. For the marine environment currently such modelling instruments are lacking. This report gives an overview of modelling instruments that are developed for marine biodiversity or its components. Next to this overview also an overview of marine biodiversity policies and their objectives is given. Modelling instruments are discussed in the context of their applicability for policy targets and their scientific pros and cons. Moreover, an overview of models developed within IMARES is given as well as an in-depth discussion on the food web model Ecopath with Ecosim, a model targeted by PBL as high potential.

Keywords: Marine Strategy Directive, North Sea, Drivers, impact assessment, biodiversity, ecosystem models, population models

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Preface

This report is the first result of an ongoing project commissioned by the Netherlands Environmental Assessment Agency (PBL) and carried out by IMARES. The aim of the project is to develop modelling instruments that can be used to assess the impact of policy and socio-economic development in the marine environment of the North Sea. This first result gives an overview of biodiversity policies targeting the biodiversity of the North Sea and modelling instruments developed to describe marine biodiversity components. Contact from within PBL was Rick Wortelboer.

Chris Klok,
Project manager

Contents

Summary

Currently the North Sea is under strong pressure, due to increased activities of traditional use such as shipping and fishing, but also increase in less traditional forms of use such as tourism and sports and even recently new forms of use such as wind mill parks. For example overexploitation of North Sea fisheries is now a major threat to biodiversity and ecosystem health. Most of the stocks of commercial fish species in the North Sea are in seriously endangered condition with *30 to 40 % of the biomass* of these species being caught each year. In addition, *70%* of young cod, for example, die before sexual maturity.

Policy development on marine biodiversity protection has lacked behind such development on terrestrial biodiversity. This situation is expected to improve for the North Sea with the European Marine Strategy Directive, which came into force in 2008.

To assess the impact of policies and societal development on biodiversity targets the Netherlands Environmental Assessment Agency (PBL) seeks to develop modelling instruments. Compared to terrestrial biodiversity, for which modelling instruments have been developed by PBL over the last two decades, the impact of policies and societal development in marine biodiversity is difficult to estimate since modelling instruments for the marine environment are currently lacking.

In this report a non extensive overview of marine modelling instruments is given. Biodiversity targets set by relevant marine policies and conventions (MSD, OSPAR, Birds and Habitats Directives) differ but can be categorized in three groups, setting targets for:
- Environmental quality
- Species
- Habitats or areas

The modelling instruments are ranked on their applied value for marine policy targets and their scientific pros and cons are discussed.

Generally speaking the larger models (in a sense of involving more components) the more difficult to parameterise, the less easy to analyse (usually by simulation only) and the less valuable (generality and robustness) are their results. Ecosystem models including many components of the ecosystem are often seen as having a high level of reality, however, these models obviously do not include complex dynamics between components. If including such complex dynamics model behaviour may become very complex ending in chaos.

The behaviour of less complex models such as species models can be analytically traced and therefore their results are more robust and general.

An overview of ecological models developed within IMARES and an in-depth discussion on Ecopath with Ecosim, a food web model that has been targeted by PBL as high potential and which has already been applied to assess the impact of policies on marine biodiversity at a global scale (EcoOcean), can be found in the appendixes.

1 Introduction

Knowlegde requirements and objective of this study

The importance of protecting biodiversity has been widely acknowledged on the international political arena. Countries participating in The Convention on Biological Diversity (CBD) have committed themselves ‘to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on earth’ (UNEP, 2002). The EU member countries have adopted an even more ambitious target, not only to significantly reduce but to halt the decline in biodiversity by 2010 (EC, 2001). The implementation of all policies affecting biodiversity should contribute towards meeting this goal.

Whereas terrestrial fauna experienced declines resulting from exploitation already over centuries, marine fauna is specifically threatened over the last century resulting from increased fisheries and unintended incidental take or by catch (Lewison *et al.*, 2004). Currently nearly 75% of the world’s marine capture fisheries are considered to be fully or overexploited and have essentially reached their maximum potential at about 100 million metric tonnes/year (FAO, 2006). In an assessment on the costs of the loss of biodiversity resulting from not taking action (COst of Policy Inaction, COPI) only for the loss of provisioning services of the marine environment (specifically fisheries) a value *$ 84,900 million* was calculated (Braat & ten Brink, 2008). Also in the North Sea loss of provisioning services is expected to be large (see Box 1).

Box 1: Loss of the North Sea provisioning services

The North Sea is one of the most productive areas in the world with a range of plankton, fish, seabirds and benthic communities and is one of the world’s most important fishing grounds. It accounts for some *2.5 million metric tonnes* of fish and shellfish catches annually and a fishing industry with significant jobs including catching, processing, transportation and shipbuilding. Overexploitation of North Sea fisheries is now a major threat to biodiversity and ecosystem health. Most of the stocks of commercial fish species in the North Sea are in seriously endangered condition with *30 to 40 % of the biomass* of these species being caught each year. In addition, *70%* of young cod, for example, die before sexual maturity. Furthermore, heavy fishing pressure has resulted in *80%* mortality in young fish. The levels of by-catch of particularly harbour porpoises (ca *7000*), pose a particular risk to overall populations. About *2.5 million* pairs of seabirds breed around the coasts of the North Sea. In 2004, seabirds on the North Sea coast of Britain suffered a large-scale breeding failure. There were strong indications that this breeding failure was linked to a food shortage caused by high levels of fishing for sandeels. The beam trawling in the southern and central North Sea reduces total benthic biomass by *39%* and benthic production by *15%* relative to the un-fished state. It is also estimated that for *1 kilogram* of North Sea sole caught by beam trawl on the seabed, *14 kilograms* of other animals are killed. The spawning stock biomass of Cod had declined from a peak of *250,000 tonnes* in the early 1970s to less than *40,000 tons* in 2001. The biomass of top predators has decreased with *65%* in 50 years. Other services affected by biodiversity loss include marine tourism and recreational services that include bird watching, whale watching and sea angling. The value of the whole production chain from fishing, aquaculture, processing to marketing is estimated to be approximately *0.28 %* of the EU gross domestic product. In Europe, the number of fishermen has been declining in recent years, with the loss of *66,000 jobs* in the harvesting sector. (Braat & ten Brink, 2008)

Policy development on marine biodiversity protection lacks behind such development on terrestrial biodiversity. But with the European Marine Strategy Directive, which came into force in 2008, this situation is expected to improve for the North Sea.

The Netherlands Environmental Assessment Agency (PBL) seeks to develop modelling instruments to assess the impact of policies and societal development, aiming at support to policy making. Compared to terrestrial biodiversity, for which modelling instruments have been developed by PBL over the last two decades, the impact of policies and societal development in marine biodiversity is difficult to estimate since modelling instruments for the marine environment are lacking.

This report gives an non extensive overview of relevant marine biodiversity policies and applicable models to assess marine biodiversity or one of its components. Furthermore, the pros and cons of model types in relation to their applied value for PBL issues is discussed. An overview of ecological models developed within IMARES and an in-depth discussion on Ecopath with Ecosim, a food web model that has been targeted by PBL as high potential and which has already been applied to assess the impact of policies on marine biodiversity at a global scale (EcoOcean), can be found in the appendixes.

Netherlands Environmental Assessment Agency and its activities

The Netherlands Environmental Assessment Agency (PBL) is a governmental institute that supports national and international policy makers by analysing the environmental impact of policies and of trends in society. PBL provides independent integrated assessments on topics such as sustainable development, energy and climate change, biodiversity, transport, land use and air quality. The results of these assessments are available to the public. PBL functions as an interface between science and policy.

Questions that PBL considers are:

- How polluted are the Netherlands, Europe and the world, and what are the implications and prospects for people, plants and animals? What is the fate of biodiversity?
- What is the environmental role in economic and social developments, both nationally and internationally? What does climate change mean for the Netherlands and the rest of the world?
- What are governments doing to protect biodiversity? Are they doing enough? What does it cost? Where can improvements be made? How effective are they?
- What factors contribute to sustainable development and in what dimension (socio-cultural, ecological or economic)?

Biodiversity, a term combining 'biological' and 'diversity' refers to the variety of life on earth (plants, animals, fungi and micro-organisms) as well as to the communities that they form and the habitats in which they live. The Convention on Biological Diversity (CBD) of the United Nations gives a formal definition of biodiversity in Article 2: 'biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems'. For the work on international environmental research (in terrestrial and inland water environment), PBL has developed several models to support policy-making processes. Well-known PBL models are the Integrated Model to Assess the Global Environment (IMAGE). IMAGE has been used for the implementation of the SRES scenarios of the Intergovernmental Panel on Climate Change (IPCC), the Global Environment Outlook (GEO) scenarios of UNEP and the Millennium Ecosystem Assessment (MA) scenarios. IMAGE is a dynamic integrated assessment modelling framework for global change. The main objectives of IMAGE are to contribute to scientific understanding and support decision-making by quantifying the relative importance of major processes and interactions in the society biosphere-climate system. Moreover, a sound empirical base is of vital importance for PBL's environmental research and integrated assessment work. Numerous core data sets at various geographical scales are acquired from various sources, including monitoring networks, statistical surveys, digital maps and satellite imagery. The GLOBIO3 model, for instance, uses quantitative relationships between environmental pressure factors and biodiversity, based on state-of-the-art knowledge from literature. By combining the results related to individual pressures, the overall change in biodiversity is calculated in terms of Mean Species Abundance of original species (MSA) and the extent of ecosystems (for more information on PBL see www.pbl.nl).

History of the project

The current study is one in a series of studies initiated by PBL to develop knowledge, databases, indicators and meta(models) with the aim to improve assessment of impacts of policy on marine ecosystems. Earlier studies conduced by IMARES resulted in a series of reports including evaluation of the current status of marine biodiversity; evaluation of indicators; evaluation of policies; study on the indicators (Aarts *et al.*, 2008; Van Densen & Van Overzee, 2008; Lindeboom *et al.*, 2008b; Meesters *et al.*, 2008, 2009, in prep.). The results of these studies were used in the Nature Balance 2008 of PBL (PBL, 2008).

2 Marine Biodiversity Policies for the North Sea

2.1 Introduction

Development of biodiversity policy and legislation for marine habitats lacked behind such development of terrestrial and inland water habitats. North Sea management recently tended to be mainly based on national policy, in line with international agreements such as the OSPAR convention (The 1992 Convention for the Protection of the Marine Environment of the North-East Atlantic) and the IMO convention (Convention on the International Maritime Organization). European policy and legislation seemed to be limited to land and inland waters. However, during the last decade, Europe has focused more on its marine environment as can be inferred from the Water Framework Directive (WFD), the Marine Strategy Directive (MSD), and the implementation of the Birds & Habitats Directives (B&HD) in marine protected areas (MPA).

The Water Framework Directive has been adopted in 2000. Its focus is to protect all waters up to 12 miles from the coast. Objectives are set within River Basin plans, to ensure all waters meet 'good ecological status' by 2015.

The Birds Directive (BD) which came into force in 1979, requires the establishment of Special Protection Areas (SPAs) for birds. The in 1992 adopted Habitats Directive (HD) similarly requires Special Areas of Conservation (SACs) to be designated for other species, and for habitats. Together, SPAs and SACs make up the Natura 2000 series.

The Marine Strategy Directive (MSD) has been adopted in 2008 and has the objective to protect, conserve and improve the quality of the marine environment in the European marine waters, through the achievement of good environmental status within a defined time period. Whereas the objectives of the WFD and B&HD are enforced those of the MSD are efford based. Planning and implementation of the MSD takes place on a regional level using an ecosystem based approach. Given the fact that biodiversity policies such as WFD, B&HD and MSD can overlap, the MSD includes WFD elements and sets B&HD goals for its MPAs. It is generally expected that OSPAR is the forum through which regional implementation of the MSD will be arranged.

2.2 International conventions and policies

2.2.1 General

The North Sea is protected by the OSPAR Convention which is a convention for the Protection of the Marine Environment in the North-East Atlantic of 1992 (further to earlier versions of 1972 and 1974). OSPAR is the mechanism by which fifteen Governments of the western coasts and catchments of Europe, together with the European Community, cooperate to protect the marine environment of the North-East Atlantic. It started in 1972 with the Oslo Convention against dumping. It was broadened to cover land-based sources and the offshore industry by the Paris Convention of 1974. These two conventions were unified, up-dated and extended by the 1992 OSPAR Convention. The new annex on biodiversity and ecosystems was adopted in 1998 to cover non-polluting human activities that can adversely affect the sea.

The fifteen Governments are Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom. Finland is not on the western coasts of Europe, but some of its rivers flow to the Barents Sea, and historically it was involved in the efforts to control the dumping of hazardous waste in the Atlantic and the North Sea. Luxembourg and Switzerland are Contracting Parties due to their location within the catchments of the River Rhine.

Ecological Quality Objectives (EcoQOs) were developed by OSPAR to promote a healthy and sustainable marine environment (OSPAR Commission, 2007). These EcoOQs (see Appendix 1) have become a model for the new European Marine Strategy Directive.

2.2.2 The Marine Strategy Directive

Of the EU directives dealing with the biodiversity of the North Sea: The Water Framework Directive (WFD); The Marine Strategy Directive (MSD); and The Birds & Habitats Directives, The Marine Strategy Directive is the most recent. This directive aims at **one protection regime for all European seas** (European Commission, 2005; European Union, 2008). It aims are:

- To strengthen the enforcement of all environmental regulations which are in place for all European seas;
- To streamline all monitoring and assessments for the present and future;
- To develop a European standard for monitoring and assessment;
- To tackle cross-border environmental issues;
- To create consistency in the implementation of 'Programmes of Measures';
- To realize uniformity within the EU environmental policy regarding the oceans and seas.

The goal of the Marine Strategy Framework Directive is in line with the objectives of the Water Framework Directive which requires surface freshwater and ground water bodies - such as lakes, streams, rivers, estuaries, and coastal waters - to be ecologically sound by 2015 and that the first review of the River Basin Management Plans should take place in 2020.

Overview of Marine Strategy Directive

Policy	Marine Strategy Directive
Scope	European seas and coastal waters (EEZ, Territorial Sea)
Dutch authority	Ministry of Transport, Public Works and Water Management
Adoption	17-07-2008
Status	legal
	Into force 20 days after official publication (17-07-2008)
Further information	http://ec.europa.eu/environment/water/marine.htm

The key-elements of the Marine Strategy Directive are:

- A dual EU/Regional approach;
- A knowledge-based approach;
- An ecosystem-based approach;
- A cooperative approach.

The dual EU/Regional approach is reflected in Figure 1

In developing their marine strategies, Member States should use, where practical and appropriate, existing regional cooperation structures, including those under regional sea conventions to co-ordinate among themselves and to make every effort to coordinate their actions with those of third countries in the same region or sub region.

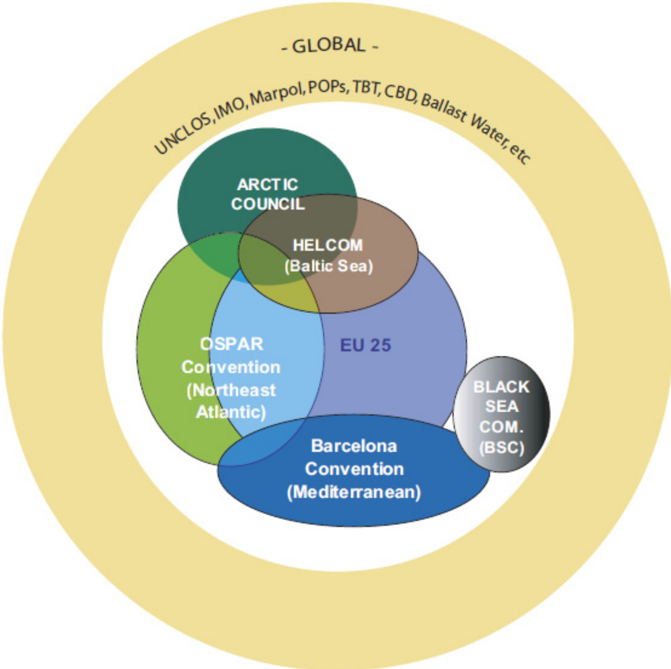


Figure 1. The institutional framework for the protection of Europe's seas and oceans (EC, 2006).

There are several regional conventions within the European marine waters and also global conventions and laws, like the International Maritime Organization (IMO) and the United Nations Convention for the Law of the Sea (UNCLOS), that are relevant. The MSD is aiming to make maximum use of regional organizations, for example OSPAR, in implementing the Directive.

The Marine Strategy Directive has three major objectives:

- Marine Strategies shall be developed and implemented with the aim of achieving or maintaining **good environmental status** in the marine environment by the year 2020 at the latest.
- The Marine Strategy Directive applies an **ecosystem-based approach** to the management of human activities while enabling the sustainable use of marine goods and services.
- The Marine Strategy Directive contributes to **coherence between**, and shall aim to ensure the integration of environmental concerns into the **different policies**, agreements and legislative measures which have an impact on the marine environment.

The definition of good environmental status given by the Commission (European Commission, 2008) is rather broad: " **'good environmental status'** means the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations, i.e.: (a) the structure, functions and processes of the constituent marine ecosystems, together with the associated physiographic, geographic, geological and climatic factors, allow those ecosystems to function fully and to maintain their resilience to human-induced environmental change. Marine species and habitats are protected, human-induced decline of biodiversity is prevented and diverse biological components function in balance; (b) hydro-morphological, physical and chemical properties of the ecosystems, including those properties which result from human activities in the area concerned, support the ecosystems as described above. Anthropogenic inputs of substances and energy, including noise, into the marine environment do not cause pollution effects; 'pollution' means the direct or indirect introduction into the marine environment, as a result of human activity, of substances or energy, including human-induced marine underwater noise, which results or is likely to result in deleterious effects such as harm to living resources and marine ecosystems, including loss of biodiversity, hazards to human health, the hindering of marine activities, including fishing, tourism and recreation and other legitimate uses of the sea, impairment of the quality for use of sea water and reduction of amenities or, in general, impairment of the sustainable use of marine goods and services."

Ecosystem-based management of human activities is best reflected in Figure .

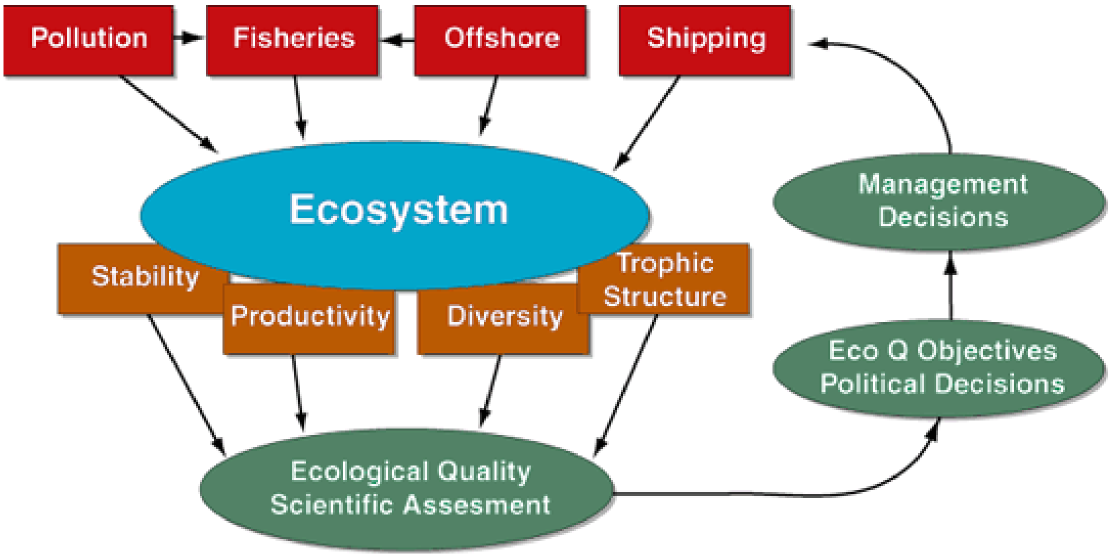


Figure 2. Schematic representation of Ecosystem-based Management.

Ecosystem-based management means the assessment of the effects of human use on relevant features of the marine ecosystem. The next step will be taking political decisions and set Ecological targets, such as the Ecological Quality Objectives (EcoQO; OSPAR Commission, 2007) developed within OSPAR, with the aim to reach good environmental status (see Appendix 2 for descriptors of good environmental status set by the MSD)). The third step will be taking management decisions with respect to human use in order to reach the ecological objectives. Finally, based on monitoring, the effects will be evaluated and assessed again and, if necessary, the procedure will be repeated.

In order to achieve the above mentioned objectives, **a transparent and coherent legislative framework** is required. This framework should contribute to coherence between different policies and foster the integration of environmental concerns into other policies, such as the Common Fisheries Policy, the Common Agricultural Policy and other relevant Community policies. The legislative framework should provide an overall framework for action and enable the action taken to be coordinated, consistent and properly integrated with action under other Community legislation and international agreements.

The Marine Strategy Directive should also support the strong position taken by the Community, in the context of the Convention on Biological Diversity, on halting biodiversity loss, ensuring the conservation and sustainable use of marine biodiversity, and on the creation of a global network of marine protected areas by 2012. Additionally, it should contribute to the achievement of the objectives of the Seventh Conference of the Parties to the Convention on Biological Diversity, which adopted an elaborate programme of work on marine and coastal biodiversity with a number of goals, targets and activities aimed at halting the loss of biological diversity nationally, regionally and globally and at securing the capacity of the marine ecosystems to support the provision of goods and services, and a programme of work on protected areas with the objective of establishing and maintaining ecologically representative systems of marine protected areas by 2012. The obligation for Member States to designate Natura 2000 sites under the Birds Directive and the Habitats Directive will make an important contribution to this process.

Measures regulating fisheries management can be taken in the context of the Common Fisheries Policy, as set out in Council Regulation (EC) No 2371/2002 of 20 December 2002 on the conservation and sustainable exploitation of fisheries resources under the Common Fisheries Policy, based on scientific advice with a view to supporting the achievement of the objectives addressed by this Directive, including the full closure to fisheries of certain areas, to enable the integrity, structure and functioning of ecosystems to be maintained or restored and, where appropriate, in order to safeguard, inter alia, spawning, nursery and feeding grounds. Articles 30 and 31 of the Euratom Treaty (1957) regulate discharges and emissions resulting from the use of radioactive material and this Directive should therefore not address them. The Common Fisheries Policy, including in the future reform, should take into account the environmental impacts of fishing and the objectives of this Directive.

Each Member State should develop a marine strategy for its marine waters which, while being specific to its own waters, reflects the overall perspective of the marine region or subregion concerned. Marine strategies should culminate in the execution of programmes of measures designed to achieve or maintain good environmental status. Specific action is not required if there is no significant risk to the marine environment, or where the costs would be disproportionate taking account of the risks to the marine environment, provided that any decision not to take action is properly justified.

Member State are obliged to develop marine strategies for their marine waters including:

- An initial assessment, to be completed by 15 July 2012 of the current environmental status of the waters concerned and the environmental impact of human activities thereon, in accordance with Article 8 of the MSD;
- A determination, to be established by 15 July 2012 of good environmental status for the waters concerned, in accordance with Article 9(1) of the MSD;
- Establishment, by 15 July 2012, of a series of environmental targets and associated indicators, in accordance with Article 10(1) of the MSD;
- Establishment and implementation, by 15 July 2014 except where otherwise specified in the relevant Community legislation, of a monitoring programme for ongoing assessment and regular updating of targets, in accordance with Article 11(1) of the MSD.

For the initial assessment member states are suggested to take account of existing data where available. The initial assessment should comprise the following: (a) an analysis of the essential features and characteristics, and current environmental status of the waters, based on the indicative lists of elements set out in Table 1 of Annex III of the directive (see Appendix 3), and covering the physical and chemical features, the habitat types, the biological features and the hydro-morphology; (b) an analysis of the predominant pressures and impacts, including human activity, on the environmental status of those waters which: (i) is based on the indicative lists of elements set out in Table 2 of Annex III of the directive (see Appendix 3), and covers the qualitative and quantitative mix of the various pressures, as well as discernible trends; (ii) covers the main cumulative and synergetic effects; and (iii) takes account of the relevant assessments which have been made pursuant to existing Community legislation; (c) an economic and social analysis of the use of those waters and of the cost of degradation of the marine environment.

The next step towards achieving good environmental status should be the establishment of environmental targets and monitoring programmes for ongoing assessment, enabling the state of the marine waters concerned to be evaluated on a regular basis.

2.3 Dutch policies

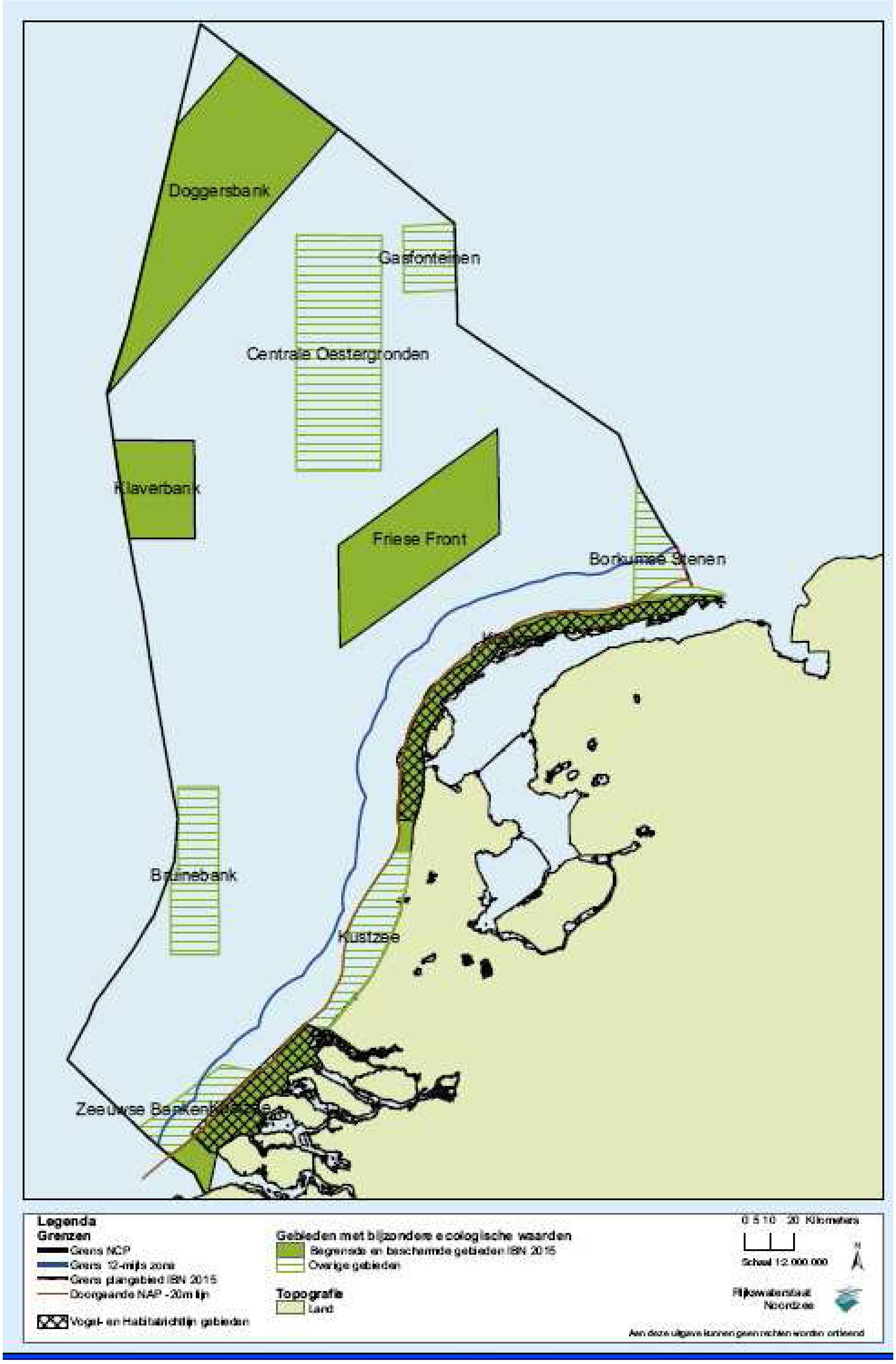
The most important Dutch policies concerning biodiversity in the North Sea are:

- Ecosysteemdoelen Noordzee;
- 4de nota waterhuishouding (NW4);
- Nota ruimte;
- Integraal beheerplan Noordzee 2015.

(for details see Nature Balance 2008 (PBL, 2008) and Van Leeuwen *et al.*, 2008).

Of these the Integrated Management Plan for the North Sea 2015 ('IBN 2015'), published in 2005 (VenW, 2005), is the most recent and overarching. The IBN 2015 reflexes international policy developments and obligations, and is based on three themes: a healthy sea, a safe sea and a profitable sea. It introduces new management instruments: the integral assessment framework for permits and the specific assessment framework for the protection of areas containing special ecological features. All activities, except those regulated internationally such as shipping and fisheries, have to go through a procedure to be legalized. This procedure "The integral assessment framework for permits" includes investigations on the spatial claim of the activity, its possible effects on the environment, the need for the activity, the need for the specific location and spatial claim, and an assessment how to reduce unwanted effects on the environment and in case of those compensation. The Dutch areas submitted for Natura 2000 (Figuur. 3) are currently in progress towards an official status.

Enforcement of International conventions and national policies is structured through the Flora and Fauna wet (FF-law) and Natuurbescherming wet (Nb-law). The Flora and Fauna wet deals with species, and the Natuurbescherming wet with nature areas and habitats. The B&H directives are integrated in the Nb-law. See Van Leeuwen *et al.* (2008) for an extensive overview.



Figuur 3. Dutch areas submitted for Natura 2000: Doggersbank, Klaverbank, Noordzeekustzone en Vlakte van de Raan. (Bos et al., 2008).

2.4 Spatial scope and authorities of most important policies

Figure 4 gives the spatial scope of the most important policies directed at biodiversity of the North Sea. As can be inferred from Table 1 different ministries are responsible for these policies.

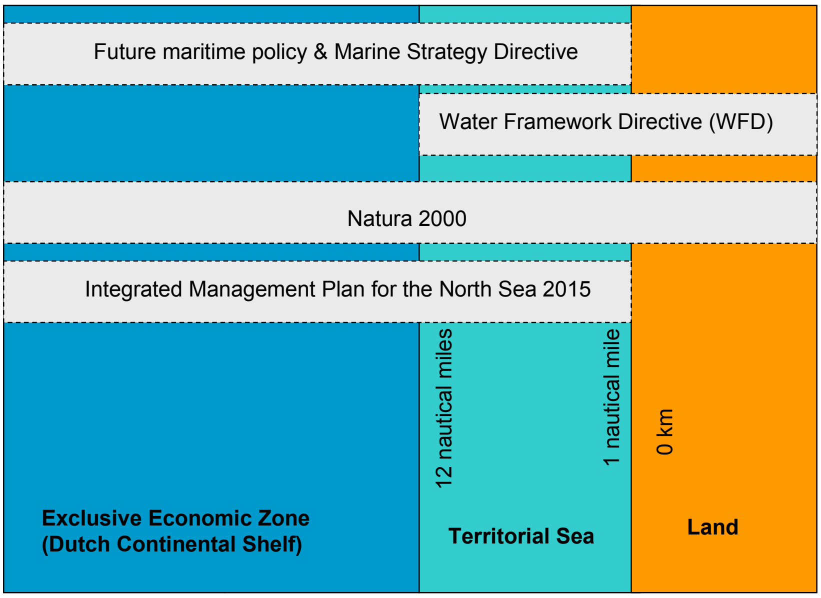


Figure 4. Schematic view of the scope of North Sea policy developments.

Table 1. Overview of recent policy developments relevant for the North Sea

Policy	Scope	Authority	Adoption	Status
Marine Strategy Directive	European seas and coastal waters	Ministry of V&W[1]	2008	Valid
Integrated Management Plan for the North Sea 2015	EEZ (Exclusive Economic Zone) and Territorial Sea	Ministry of V&W	2005	Valid
Natura 2000	European Union	Ministry of LNV [2]	2004	Valid
Water Framework Directive	All EU inland surface waters, transitional waters, coastal waters and groundwater. In respect of chemical status it also includes territorial waters	Ministry of VROM [3]	2000	Valid

[1)] Ministry of Transport, Public Works and Water Management
[2)] Ministry of Agriculture, Nature and Food Quality
[3)] Ministry of Housing, Spatial Planning and the Environment

2.5 Biodiversity targets set by policies and conventions

Biodiversity targets set by relevant policies and conventions discussed above differ between policies (compare e.g. the targets set by OSPAR (Appendix 1) and the Marine Strategy Directive (Appendix 2). All, however can be categorized in three groups, setting targets for:

- Environmental quality
- Species
- Habitats or areas

OSPAR sets next to targets on species and boundaries for the impact of human activities on species (e.g. less than 1.7% by-catch of harbour porpoise, see Appendix 1) targets for environmental quality such as oxygen and nutrient concentrations. The MSD includes in its Environmental quality objectives litter and energy, including underwater noise (see Appendix 2b).

The B&H Directives which apply to MPAs formulate their biodiversity goals as conservation of selected habitats and habitats of species and species in a favourable conservation status.

The conservation status of a natural habitat will be taken as 'favourable' when:

- Its natural range and areas it covers within that range are stable or increasing, and
- the specific structure and functions which are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future, and
- the conservation status of its typical species is favourable as defined in the B&H Directives

The conservation of a species is taken as 'favourable' when:

- Population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats, and
- The natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future, and
- There is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis;

Criteria for habitats are therefore spatial coverage, functions and structure, and species composition, whereas for species criteria are viable populations, spatial area, and amount of habitat necessary to maintain viable (meta)populations.

3 Models to analyse marine biodiversity

3.1 Introduction

How effective policies are to reach objectives on environmental quality, species and habitats, as discussed above can be analyzed with different instruments, like monitor-, and model studies. Monitoring is traditionally the most objective and straightforward way to measure the status of biodiversity. However, interpretation of monitoring data is often difficult, e.g. when trying to assess a complex ecosystem or a complete time frame. Models are often used to interpret complex or deficient monitoring data aiming at higher levels of biodiversity (e.g. population viability, ecosystem integrity etc.).

3.2 How to choose the right model?

Models are tools used to represent reality in a simplified way. The type of model chosen will depend upon the problem to be addressed, i.e. there is no need to use a sledgehammer to crack a walnut. This indicates that no single best model exists to describe all possible ecological problems. One can however develop criteria to facilitate selection of model types applicable for a specific question.

Seen from the perspective of the widely used Drivers Pressures States Impacts and Responses (DPSIR) framework (EEA, 2006), which implies the integration of socio-economic and ecological processes to understand the forces that drive patterns of biodiversity change, most ecological models inform us about States and Impacts. To be part of the DPSIR framework ecological models must at minimum be able to accept input from Pressure models and give output applicable to Response models. This gives restrictions on in- and output-parameters especially related to dimensions (space and time). The following paragraph is based on Skov *et al.* (2006) which deals with the question of model selection for nature policy questions for the terrestrial environment in which the first author of this report was strongly involved. The classification given in Skov *et al.* (2006) is also applicable for the marine environment.

3.2.1 A model classification

When communicating models and model results it is important to have insight in basic types of models and their properties.

Models can be categorized on the basis of their level of biological aggregation and spatial resolution (Figure 5). The classification shown in Figure 5 present the major modelling styles usually encountered in modelling of different aspects of biodiversity.

Distribution models - refer to the prediction of occurrence of a species in space. These models are typically GIS based information models. They pre-suppose a spatial element. Distribution models can be based on a expert opinion based or statistical descriptive of the suitability of habitats for species (**Habitat suitability models**) or more complex dynamics of habitat characteristics such as in **Coupled hydrological biochemical models**. Coupled hydrological biochemical models applied to model marine biodiversity generally simulate algal growth and the zooplankton that grazes it where the system is driven by hydrodynamics.

Higher trophic levels, such as fish are usually not included in the ecosystem part. Also the benthic compartment is often not modelled in detail, including mostly bulk processes for microbial degradation of detritus and resulting recycling of nutrients.

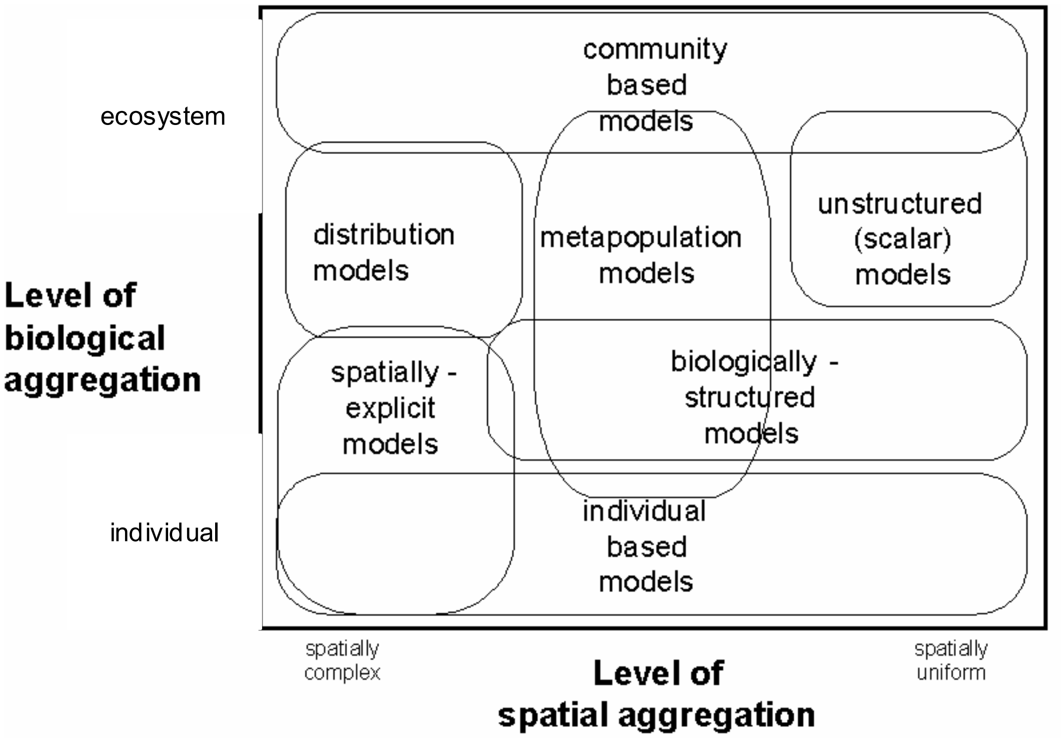


Figure 5. A proposed classification of ecological models typically used for biodiversity research (after Skov et al., 2006)).

Community Models - These models differ from the preceding models in that the community is the unit of focus. These models typical include GIS based systems and multivariate statistical models, but can also be based on sophisticated mathematical descriptions. Community models come in all degrees of ecological and spatial aggregation. In general models either include many species and are restricted in the dynamics between species (**most food web models**) or restrict the number of included species and are strong in describing the dynamic interactions between the species (**food chain models**).

Individual-based models *(IBMs)* - IBMs consider individuals as the unit of focus. Their data needs are very specific to the species modelled and they tend toward a high degree of realism (and hopefully accuracy) at the expense of generality. Two classes of IBMs are recognized: **i-state distribution** (based on partial differential equations to manage the behaviour of individuals) and **i-state configuration** (characterized as summing the behaviour of all individuals as they are modelled separately). IBMs require higher volumes of data and longer development times than biologically-structured model types. Development cycles are long, and the data volume required is high. A special case of IBM are **spatially explicit models.** These models consider next to the individuals also the characteristics of the environment, e.g. habitat quality; types; arrangements; as well as the spatial arrangement of environmental stressors. Especially the i-state configuration models are generally employed for specific case studies where their realism is necessitated by the decisions or detailed research they support.

Metapopulation models - Take into account the disjunctive spatial distribution of many natural populations by simulating these as a set of interacting sub-populations. The level of biological aggregation can encompass indices, species and individuals. This modelling format has been extensively used in the past in terrestrial environments. For those systems compatible with the assumptions of the model, metapopulation models represent a relatively easy approach to implement and parameterize. Levels of realism can be scaled according to the data availability and aims.

Biologically-structured models - These models assign demographic characteristics or vital rates to unique classes of individuals in the population. The vital rates can either be constant, time or age dependent or based on **Dynamic Energy Budget** parameters (Kooijman, 2000) which can directly be related to drivers. Typical implementations involve the use of projection matrix representations such as the Leslie model.

Biologically structured models can incorporate discrete time events such as reproduction and can include time-dependent variation in vital rates. Other implementations include a variety of differential equation based models.

Scalar models - Probably the simplest form is that suggested by Malthus in 1798: dN/dt=rN (where N is population size, t is time and r is birth-death rate). Assumptions are that the population can be represented as a single uniform entity, no demographic or environmental structure, and usually few variables describing specific properties. Their uncomplicated and aggregated nature emphasizes generality at the expense of realism and accuracy.

3.2.2 Model types applied in marine biodiversity issues

Distribution models such as coupled hydrological biochemical models form a large part of the literature on marine biodiversity models. These models usually are developed to simulate spatial patterns in primary production. More ecological complexity may arrive if next to primary producers also higher trophic levels are simulated. A large literature review on these models has been published by (Moll & Radach, 2003), who compared eleven different coupled 3D-hydrodynamic-biogeochemical models for the North Sea shelf system (see Appendix 4). Moll & Radach (2003) concluded that these models have either confirmed existing knowledge derived from field work or have given new insight into the mechanisms of the North Sea system: the temporal and spatial development and magnitude of primary production, its limitations, the mechanisms of nutrient regeneration, and the budgets for phosphorus, nitrogen and silicon.

Given the diversity of model descriptions of primary production in distribution models, which results in very different incomparable model currencies (from nutrient load to biomass), Pereira *et al.* (2006) suggested Dynamic Budget Theory (DEB) as a theoretical framework to describe processes in a general applicable model currency. Problems with distribution models arise from their numerous state variables, which makes them analytically intractable and pose a problem regarding parameter calibration. Furthermore problems can arise from different time scales of the processes in the model where e.g. hydrodynamic phenomena in coastal zones occur at a time scales of minutes to hours and the processes of biogeochemistry acting at time scales of a few days. Pereira *et al.* (2006) conclude from the increased use of coupled models as inferred from the literature that their is a clear recognition in the scientific community of the importance to incorporate in one model the feedbacks between physical, chemical and biological processes. They furthermore state that there is not one modelling software suitable for solving all simulation challenges.

Ecosystem or food web models, such as Ecopath with Ecosim (EwE) (www.ecopath.org) and Gadget (www.hafro.is) allow for more ecological realism, by including more and interacting trophic levels.

The Ecopath approach and software was originally developed as a political instrument tot show the consequences of fishing on non target species. It was applied to describe these consequences in a coral reef system in the Northern Hawaiian Island, the French Frigate Shoals in the mid-1980s (Opitz, 1996). Given the fast rates of biomass conversion in coral reef systems, the steady state assumption of this first Ecopath version was not violated.

Ecopath allows construction of a mass balance model of a given trophic network by representing the ecosystem functional groups as interacting by means of feeding relationships and, when necessary, subjected to fishing (Christensen and Walters, 2004). The balance of mass (energy, or nutrients) for any functional group (i) of the network is obtained by setting its production equal to the sum of the consumption components, expressed as

$$\left(\frac{P}{B}\right)_i B_i = \sum_{j=1}^{n} \left(\frac{Q}{B}\right)_j B_j DC_{ij} + E_i + Y_i + BA_i + \left(\frac{P}{B}\right)_i B_i (1 - EE_i)$$

where production, on the left hand side of the equation, is expressed as the product between the production–biomass ratio (P/Bi) and the biomass (Bi), and the right-hand side terms are the sum of the predation terms, each expressed as the product of the consumption–biomass ratio (Q/Bj), the biomass of the predators (Bj) and the proportion of the prey i in the diet of the predator j (DCij); the net flow through the boundaries of the system, i.e., dispersal (Ei); the fishing exploitation, represented through the catches (Yi); the accumulation or depletion of biomass (BAi); and non-predation natural mortality, expressed by means of the ecotrophic efficiency (EEi). The resulting system of equations, when solved, provides a snapshot of the flows within a trophic web.

Gadget (Globally Area-Disaggregated General Ecosystem Toolbox) is a software tool that can run complicated statistical ecosystem models. Gadget works by running an internal model based on many ecological parameters, and then comparing the data from the output of this model to real data to get a goodness-of-fit likelihood score. Ecological features may include: one or more species, each of which may be split in stocks; multiple areas with migration between areas; predation between and within species; migration; reproduction and recruitment; multiple commercial and survey fleets taking catches from the populations. It also allows for populations to be split by size class, age group and area. Gadget works by keeping track of the number, mean weight of fish in a population cell.

Given the large number of parameters in ecosystem or food web models, these models suffer form the same drawbacks as distribution models in analytical intractability and parameter calibration.

Metapopulation models have not yet been applied to a large extent in the marine environment (but see Man *et al.*, 1995; Tuck and Possingham, 2000). This does not result from the fact that metapopulation models are not perceived as important in the marine environment but because relatively little is known about dispersal of species in different life stages. Therefore the effectiveness of MPA networks in biodiversity protection has received up to now relatively little attention (Jones *et al.*, 2007). Most approaches to the management of marine species and ecosystems are based on untested assumptions about typical larval dispersal distances (Jones *et al.*, 2007). Jones *et al.* (2007) state that understanding connectivity is critical both for the design of marine reserve networks to protect biodiversity and for the development of conservation strategies to protect species associated with degrading and fragmenting seascapes. These authors even reopen the old SLOSS (Single Large Or Several Small) debate of the 1970s and 1980s and discuss its importance for the marine environment. This discussion however, is of little value if habitat quality is not explicitly included, given that habitat quality by definition always has an overruling influence on population viability (Klok & de Roos, 1998).

It is increasingly appreciated that marine reserves “are necessary, but not sufficient” to manage exploited species or protect marine biodiversity (Allison *et al.*, 1998; Jameson *et al.*, 2002; Aronson & Precht, 2006). A comprehensive management plan must involve minimizing human impacts both inside and outside MPAs.

Individual-based, biologically structured, and scalar models are commonly used for analysis and management of fish and marine vertebrate populations (Crouse *et al.*, 1987; Tuljapurkar & Caswell, 1997). These models can be used to: assess the effectiveness of MPA's; diagnosis of population viability; assess management actions to increase population viability by assessing the relative importance of life-history aspects; analyse interaction between species; analyse the impact of invasive species on local communities; analyse the impact of drivers (human induced stressors like fisheries, pollutants, etc.) on populations and in food chains; etc. etc.

Gerber *et al.* (2003) reviewed 32 models aiming to assess the effectiveness of MPAs. They classified these models based on the features they include. Much like biological taxonomy, the models can be divided between a number of natural dichotomies: (1) single- vs. multispecies models, (2) whole life cycle vs. cohort models, (3) dispersing vs. local recruitment, (4) pre- vs. postdispersal density dependence, (5) unstructured vs. age/size structured populations, (6) dispersing vs. resident adults, (7) deterministic vs. stochastic dynamics, and (8) permanent vs. rotating reserves (see Appendix 5).

Multiple-species considerations have been limited to comparisons of responses by species with different life history traits. Even so, issues of species viability have just begun to be explored (Botsford *et al.*, 2001; Gerber *et al.*, 2002; Gaines *et al.*, 2003). In cases where the goal is to recover a threatened or endangered population, a focus on the viability, or persistence, of that population would be appropriate (Gerber *et al.*, 2003).

Individual based models vary form very specific strictly individual based, e.g. including the spatial behaviour of individuals (i-state configuration) to more general models that are based on distributions (i-state distribution). Like **distribution and food web models** the IBM i-state configuration models are given the large number of parameters usually not analytically traceable, and solutions are derived from simulations. Given the lack of analytical solutions simulation series should be long to let results become independent of initial conditions.

For the more general individual based models (i-state distribution), the structured and scalar models many analytical techniques have been developed to derive solutions, which makes there results general and robust (see e.g. Tuljapurkar & Caswell, 1997 for marine applications). Scalar models suffer form the fact that the population is considered to be not structured which implies all individuals have the same characteristics during their whole existence. Compared to structured and individual based models, that include variation between individuals (e.g. sex) and of the life-history characteristics (growth, reproduction and survival) over the life time of an individual, scalar model have relative low ecological relevance.

See Appendix 6 for marine models developed by IMARES and Appendix 7 for an in-depth discussion on EwE.

3.3 Evaluation of model types for policy objectives

As noted before the type of model chosen will depend upon the problem to be addressed and no single best model exists to describe all possible ecological problems. Different models are developed for different purposes. Table 2 gives a classification of the model types discussed in the previous paragraph on their scope and ranks their applicability for the policy objectives given in chapter 3.

Table 2. Classification of model types on overlap in their scope policy objectives

	Policy Objective		
Model type	**Species**	**Habitat**	**Environmental quality**
Distribution	+	++	+++
Community	++	+++	+
Metapopulation	+++	+	
Individual-based	+++		
Biologically structured	+++		
Scalar	+		

There are a number of criteria that are important to consider when evaluating and comparing models.

The criteria below applied in Posthuma *et al.* (2005) and Skov *et al.* (2006) strongly overlap with those developed to evaluate PBL models (Jansen, 2004):

Model scope: System/species level; The scope refers to the purposes of the model for scientific and policy aims. Furthermore, it should be noted to what extent the model is accepted for scientific and policy purposes.

Model type: Qualitative/Statistic/Mechanistic/Dynamic? Has the model an empirical (i.e. statistical) or theoretical (mechanistic) basis? What are the main assumptions? Is the model based on relevant processes? Which processes and mechanism are ignored in the model?

Model scale: What are the time and spatial scales for which a model can be applied?
Is the model restricted to a certain time or spatial scale? Can the model be extrapolated to other time or spatial scales?

Model feasibility: Is the model comprehensible? Is good documentation available? Model complexity and comprehensibility of underlying mechanisms may influence the usefulness of a model if users are not able to run the model without advanced programming or modelling knowledge. Good documentation of the model or setting up courses for novice users may aid potential users.

Model input: Data requirements? Are input parameters measurable? Does the model give reliable output for the whole range of input data?

Model output: Generality/predictability? Are the model results analytically tractable and/or can they be verified against real-world data.

Alternative models: Are there alternative models? What are the differences? If the model was compared with alternative models, the outcome of this comparison may also be presented.

Model references: What are the most important sources where the model is presented. These sources may consist of model descriptions, examples of model use, discussions on calibration and validation methods, etc.

Table 3. Summary on general aspects of model types.

	Evaluation criteria					
Model type	**Scope**	**Type**	**Feasibility**	**Data requirements**	**Output**	**References**
Distribution	communities/ habitats/ processes/ chemicals	statistic/ qualitative	complex	high	s	++
Community	species/ communities/ habitats	statistic/ qualitative	complex	high	s	++
Metapopulation	populations	dynamic	intermediate	high	s/a	++++
Individual-based	Individuals/ populations/ species	mechanistic/ dynamic/ statistic	complex/ intermediate	high	s/a	+++
Biologically structured	populations/ species	mechanistic/ dynamic	intermediate/ simple	medium	a	++++
Scalar	populations/ species/ biomass	dynamic	simple	low	a	++++

s- output is derived from simulations, a- output is based on analytical solutions
+ indicates the amount of literature on methods for the different model types, more + implies more references.

Table 3 gives an overview of the criteria used for model comparison and model evaluation. These criteria actually are developed to compare specific models and not model types, therefore some of the criteria, that only make sense when comparing specific models such as model scale and alternatives, are left out of the table. Generally speaking model scale (time and space) obviously should strongly depend on the actual characteristics of the system modelled (in case of mechanistic models one may extrapolate to scales outside the range of data the model is parameterized with, in case of statistical models one should not). Problems with scale may arrive from mismatch with scales set by policy questions.

Generally speaking the larger models (in a sense of involving more components) the more difficult to parameterise, the less easy to analyse and the less valuable (generality and robustness) are their results (Table 3). Ecosystem models including many components of the ecosystem are often seen as having a high level of reality, however, these models obviously do not include complex dynamics between components. If including such complex dynamics model behaviour may become very complex ending in chaos. Two other aspects are perhaps more troublesome. First, models that aggregate over large spatial scales, many species, and multiple age structures are likely to be less responsive to environmental changes (e.g. the effects of fishing) than models with less aggregation (Cox *et al.*, 2002). Responsiveness to environmental changes is likely to be influenced by the level of aggregation in a model (Rice, 1995), and it would be interesting to compare results with those from models with different numbers of components. Second the predator–prey dynamics in the model are limited to the family of behaviours set by the equation that is used. Rice (2001) notes that the effects of physical forcing need to be investigated in the context of consumer groups that participate in scramble competition (all consumers undergoing simultaneous periods of food shortage or excess).

For population models (from scalar to metapopulation) many analytical tools are developed to analyse their model behaviour. This makes the results of this class of models general and robust (see e.g. Tuljapurkar & Caswell, 1997 for marine applications).

3.4 Scenarios to visualize consequences of policies

Scenarios can be used to visualize the consequences of policies and socio economic development on biodiversity (Skov *et al.*, 2006). Internationally the Intergovernmental Panel on Climate Change (IPCC) has developed scenarios which are well approved of by the international community. Also the Netherlands Environmental Assessment Agency (PBL) uses scenarios to analyze impacts of societal trends and policies on the environment.

Scenarios are imaginative pictures of potential futures. The objective of scenarios is not to forecast or predict the future development of biodiversity, but to imagine a variety of possible and plausible futures (Penker & Wytrzens, 2005). Scenarios are hypothetical, describing alternative future pathways, and elements are judged with respect to importance, desirability and/or probability (EEA, 2000). Scenarios describe processes representing sequences of events over a certain period of time. Alternative policies can be evaluated in light of contrasting scenarios and their robustness to possible futures can be compared. While scenarios are often based on qualitative stories (narratives), computer models are tools to explore future consequences of assumptions and consistency of the developed scenarios in a quantitative way. Besides advising the decision-making process a key function of scenarios is its power for combining both qualitative (expert knowledge) and quantitative (data and model based) output (Rotmans & van Asselt 1996; Penker & Wytrzens, 2005).

Models and scenario analysis can provide a very powerful tool for explorative studies, provided they use reliable input data, and are based on thorough understanding of ecosystem functioning as well as of needs and demands from society. Usually forecasting biodiversity change is based on existing scenarios of a single or multiple pressures. The explicit incorporation of socio-economic drivers remains a rarity and was done particularly at the regional scale (Tasser & Tappeiner, 2002). Furthermore, integrating several scales in developing scenarios, which means being developed at one scale (e.g. continental) but including trends at other scales (global, regional), is still a rarity. The most elaborate biodiversity change scenario exercise at the global scale so far has been carried out by the Millemium Ecosystem Assessment (Millennium Ecosystem Assessment Advisory Board, 2003). In this assessment terrestrial biodiversity was modelled via the IMAGE land cover change scenario and the species-area relationship, the potential biome and species shift due to climate change, and the critical loads concept for nitrogen deposition. Clark *et al.* (2001) point out that scenarios can be uncertain as long as they are as consistent as possible with current scientific understanding and that uncertainty is communicated transparently. Much more crucial for scenarios to be successful is that priorities for ecological forecasting must come from dialogue that ensures active participation by policy-makers, managers and the general public. A first step in scenario building would thus focus on the definition of forecasting priorities via user needs. Intergovernmental Panel on Climate Change (IPCC) Scenarios have been influential because they respond to a request from governments. The use of alternative scenarios is becoming increasingly popular in environmental decision making, because scenarios combine assumptions and values in coherent packages that are easier to understand than are complex models with innumerable permutations of parameters (Kareiva, 2001).

4 Perspectives

4.1 Introduction

The North Sea is a complex open ecological system, being part of a larger marine area. Compared to terrestrial biodiversity where maps have been designed to characterise areas by their species and habitats composition, habitats and species cannot so easily be allocated to specific areas in the North Sea, and certainly not at the same level of detail (1x1 km). Among others this results from a lower intensity in monitoring in Dutch marine areas compared to terrestrial. Such that no complete data on system characteristic in biodiversity terms are currently available (see e.g. Lindeboom *et al.*, 2008a). Moreover, since the largest part of the sea bottom has relatively little structure (being sandy or muddy) currents, but also human activities like fishing with beam trawlers, strongly disturb the sediments both horizontal and vertical, resulting in relatively homogeneous areas without characteristic habitats or species. An exception are areas with hard substrate where sessile organisms such as mussels and oysters settle. These areas usually have a high biodiversity (Lindeboom *et al.*, 2008a). In earlier days the North Sea existed of larger areas of hard substrate such as the "Oesterbanken" (Olson, 1883 in Lindeboom *et al.*, 2008a). Fisheries for benthic fauna however, demolished most of these hard substrate areas.

The problem of how to spatially characterize the North Sea is not only an issue for biodiversity, but also of human use of the North Sea, and their consequences like eutrophication. Data on landings of fish are still on the scale of ICES blocks, which is not very detailed considered their size (56x56km). For some human activities data are available on a less coarse scale (see Nature Balance 2008 page 111; PBL, 2008). Currently the North Sea is under strong pressure, due to increased activities of traditional use such as shipping and fishing, but also increase in less traditional forms of use such as tourism and sports and even recently new forms of use such as wind mill parks. Still the most important drivers of biodiversity loss in North Sea are considered fisheries and eutrophication.

Policy by definition has a spatial context, for example consider the IBN 2015 and its integral assessment framework for permits for activities and their possible impact. The use of scenarios to assess possible impacts of policies and socio-economic developments also necessitates a spatial scale to visualize where impacts may be largest.

4.2 Visualize bottlenecks qualitatively using expert knowledge

Given the lack of detailed spatial insight in both biodiversity (where is what) and pressures (what works where) a good strategy is first to visualize possible bottlenecks by:

- Develop pressure maps (quantitative influence of drivers) of the North Sea GIS based: nutrients, different types of fisheries, pollutants, wind parks, underwater noise etc. Use MDS Appendix 2 to choose objectives;
- Develop multipressure maps, combining the different pressures;
- Develop GIS based biodiversity maps (habitats, species, communities of special interest etc.);
- Develop biodiversity hotspot maps. First action taken by Lindeboom *et al* (2008b);

- Discuss these maps and their overlays with a group of experts to rank bottlenecks; areas with high biodiversity and high pressures.

These bottlenecks can be the first focus of further inquiry.

4.3 Develop scenarios and evaluate with experts

Based on policies and socio-economic development scenarios can be developed to assess the impact on those components of biodiversity that were identified as important bottlenecks by the expert groups. Scenarios can be focussed on a single or a multitude of drivers like fisheries, eutrophication, pollution, invasive species etc.

If scenarios involve changes in fisheries the EwE model is probably the best model to apply since it acts on the scale of interest of PBL (North Sea) and can cope with the scale at which imput data are provided (ICES blocks). Morever, a EwE version of the North-Sea has been developed at CEFAS (UK) (Mackinson & Daskalov, 2008). Results will be in the form of differences in fish biomass in the system under the restriction that change in fisheries does not change relations between components of the model, e.g. food chain relations do not change. EwE is based on linear equations and the principle of mass balance, therefore only small deviations from the current system can be expected to give informative results, large deviations need a new calibration round. Given the possibility that scenarios may impede large deviations, and therefore results of EwE may become uncertain, a good strategy seems to be to depict the results of EwE for a number of scenarios and evaluate and discuss these with expert groups.

The EwE results are not only restricted to species involved in the EwE model food chain (fish, some marine mammals and some birds) but can also be informative for other species that feed on those. These discussed results of the EwE model can be used to draw maps of food availability for species that are part of the B&H Directives for which more information is needed.

The various expertise fields within IMARES encompass different aspects relating to the development of Biodiversity in the North Sea in relation to external factors such as eutrophication and fishing pressure. None of these approaches (including EwE) is a "one size – fits all" approach, and in particular, depending on the policy questions at hand, a combination of these approaches will be more fruitful approach. For instance, for certain species, not included in EwE, a combination of the population viability approach in combination with EwE may be fruitful. In this case EwE could be used to food and mortality conditions for a species of concern, these can then be used as inputs for population viability models. Linking cellular automata with Ecopath/Ecosim (as is done in Ecospace) is a fruitful approach for determining the spatial extent of focus species in a dynamic manner.

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Appendix 1 Ecological Quality Objectives of OSPAR

a. Ecological Quality Objectives EcoQOs (Meesters et al 2009)

Issue	Ecological quality element
1) Commercial fish species	Spawning stock biomass of commercial fish species
2) Threatened and declining species	Presence and extent of threatened and declining species in the North Sea
3) Sea mammals	Seal population trends in the North Sea Utilisation of seal breeding sites in the North Sea By-catch of harbour porpoises
4) Sea birds	Proportion of oiled common guillemots among those found dead or dying on beaches Mercury concentrations in seabird eggs and feathers Organochlorine concentrations in seabird eggs Plastic particles in stomachs of seabird Local sand eel availability to black kittiwakes Seabird populations trends as an index of seabird community health
5) Fish communities	Changes in the proportion of large fish and hence the average weight and average maximum length of the fish community
6) Benthic communities	Changes/kills in zoobenthos in relation to eutrophication Imposex in dog whelk Density of sensitive species Density of opportunistic species
7) Plankton communities	Phytoplankton Chlorofyl a Phytoplankton indicator species for eutrophication
8) Habitats	Restore and/or maintain habitat quality
9) Nutrient budgets and production	Winter nutrient (DIN and DIP) concentrations
10) Oxygen consumption	Oxygen

b. Selection of the above EcoQOs and their target used in the pilot study of Meesters et al. (2009)

Ecological quality element	Ecological quality objective
a) Spawning stock biomass of commercial fish species	Above precautionary reference points for commercial fish species where these have been agreed by the competent authority for fisheries management
c) Seal population trends in te North Sea	No decline in population size or pup production of ≥ 10% over a period of up to 10 years
e) By-catch of harbour porpoises	Annual by-catch levels should be reduced to levels below 1.7 % of the best population estimate
f) Proportion of oiled Common Guillemots among those found dead or dying on beaches	The proportion of such birds should be 10% or less of the totla found dead or dying in all areas of the North Sea
m) Changes/kills in zoobenthos in relation to eutrophication	There should be no kills in benthic animal species as a result of oxygen deficiency and/or toxic phytoplankton species
n) Imposex in dog whelks	A low (<2) level of imposex in female dog whelks, as measured by the Vas Deferens Sequence index
q) Phytoplankton chlorophyll a	Maximum and mean chlorophyll a concentrations during the growing season should remain below elevated levels, defined as concentrations > 50% above the spatial (offshore) and/or historical background concentration
r) Phytoplankton indicator species for eutrophication	Region/area – specific phytoplankton eutrophication indicator species should remain below respective nuisance and/or toxic elevated levels (and increased duration)
t) Winter nutrient concentrations (DIN and DIP)	Winter DIN and/or DIP should remain below elevated levels, defined as concentrations > 50% above salinity related and/or region-specific natural background concentrations
u) Oxygen	Oxygen concentration, decreased as an indirect effect of nutrient enrichment, should remain above region-specific oxygen deficiency levels, ranging from 4-6 mg oxygen per litre

Appendix 2 Good Environmental status (MSD) descriptives

ANNEX I

Qualitative descriptors for determining good environmental status
(referred to in Articles 3(5), 9(1), 9(3) and 24)

(1) Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.

(2) Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems.

(3) Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.

(4) All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.

(5) Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters.

(6) Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.

(7) Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.

(8) Concentrations of contaminants are at levels not giving rise to pollution effects.

(9) Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards.

(10) Properties and quantities of marine litter do not cause harm to the coastal and marine environment.

(11) Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

To determine the characteristics of good environmental status in a marine region or subregion as provided for in Article 9(1), Member States shall consider each of the qualitative descriptors listed in this Annex in order to identify those descriptors which are to be used to determine good environmental status for that marine region or subregion. When a Member State considers that it is not appropriate to use one or more of those descriptors, it shall provide the Commission with a justification in the framework of the notification made pursuant to Article 9(2).

Appendix 3 MSD suggested Ecological Characteristics Pressures and Impacts on which ecosystems should be evaluated and described.

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ANNEX II

Indicative lists of characteristics, pressures and impacts

(referred to in Articles 8(1), 9(1), 9(3), 10(1), 11(1) and 24)

Table 1

Characteristics

Physical and chemical features	— Topography and bathymetry of the seabed, — annual and seasonal temperature regime and ice cover, current velocity, upwelling, wave exposure, mixing characteristics, turbidity, residence time, — spatial and temporal distribution of salinity, — spatial and temporal distribution of nutrients (DIN, TN, DIP, TP, TOC) and oxygen, — pH, pCO2 profiles or equivalent information used to measure marine acidification.
Habitat types	— The predominant seabed and water column habitat type(s) with a description of the characteristic physical and chemical features, such as depth, water temperature regime, currents and other water movements, salinity, structure and substrata composition of the seabed, — identification and mapping of special habitat types, especially those recognised or identified under Community legislation (the Habitats Directive and the Birds Directive) or international conventions as being of special scientific or biodiversity interest, — habitats in areas which by virtue of their characteristics, location or strategic importance merit a particular reference. This may include areas subject to intense or specific pressures or areas which merit a specific protection regime.
Biological features	— A description of the biological communities associated with the predominant seabed and water column habitats. This would include information on the phytoplankton and zooplankton communities, including the species and seasonal and geographical variability, — information on angiosperms, macro-algae and invertebrate bottom fauna, including species composition, biomass and annual/seasonal variability, — information on the structure of fish populations, including the abundance, distribution and age/size structure of the populations, — a description of the population dynamics, natural and actual range and status of species of marine mammals and reptiles occurring in the marine region or subregion, — a description of the population dynamics, natural and actual range and status of species of seabirds occurring in the marine region or subregion, — a description of the population dynamics, natural and actual range and status of other species occurring in the marine region or subregion which are the subject of Community legislation or international agreements, — an inventory of the temporal occurrence, abundance and spatial distribution of non-indigenous, exotic species or, where relevant, genetically distinct forms of native species, which are present in the marine region or subregion.
Other features	— A description of the situation with regard to chemicals, including chemicals giving rise to concern, sediment contamination, hotspots, health issues and contamination of biota (especially biota meant for human consumption), — a description of any other features or characteristics typical of or specific to the marine region or subregion.

Table 2

Pressures and impacts

Physical loss	— Smothering (e.g. by man-made structures, disposal of dredge spoil), — sealing (e.g. by permanent constructions).
Physical damage	— Changes in siltation (e.g. by outfalls, increased run-off, dredging/disposal of dredge spoil), — abrasion (e.g. impact on the seabed of commercial fishing, boating, anchoring), — selective extraction (e.g. exploration and exploitation of living and non-living resources on seabed and subsoil).
Other physical disturbance	— Underwater noise (e.g. from shipping, underwater acoustic equipment), — marine litter.
Interference with hydrological processes	— Significant changes in thermal regime (e.g. by outfalls from power stations), — significant changes in salinity regime (e.g. by constructions impeding water movements, water abstraction).
Contamination by hazardous substances	— Introduction of synthetic compounds (e.g. priority substances under Directive 2000/60/EC which are relevant for the marine environment such as pesticides, anti-foulants, pharmaceuticals, resulting, for example, from losses from diffuse sources, pollution by ships, atmospheric deposition and biologically active substances), — introduction of non-synthetic substances and compounds (e.g. heavy metals, hydro-carbons, resulting, for example, from pollution by ships and oil, gas and mineral exploration and exploitation, atmospheric deposition, riverine inputs), — introduction of radio-nuclides.
Systematic and/or intentional release of substances	— Introduction of other substances, whether solid, liquid or gas, in marine waters, resulting from their systematic and/or intentional release into the marine environment, as permitted in accordance with other Community legislation and/or international conventions.
Nutrient and organic matter enrichment	— Inputs of fertilisers and other nitrogen — and phosphorus-rich substances (e.g. from point and diffuse sources, including agriculture, aquaculture, atmospheric deposition), — inputs of organic matter (e.g. sewers, mariculture, riverine inputs).
Biological disturbance	— Introduction of microbial pathogens, — introduction of non-indigenous species and translocations, — selective extraction of species, including incidental non-target catches (e.g. by commercial and recreational fishing).

Appendix 4 Distribution models

Implementation of 'key process complexes' in the selected models. For each 'key process complex' a short list of necessary criteria was defined, with SV = state variables, FU = functional units, SP model = structured population model, IB model = individual basedmodel, HM = heavy metal, PCB = polychlorinated biphenyl (from Moll et al., 2003).

Criteria	Algae blooms	Nutrient regeneration	Eutrophication	Tropic relations	Recruitment	Pelagic- benthic coupling	Conta-minants
Model name	Phytopl. succession; nut. limitation	particulate and dissolved organic matter	nut: N/P ratio; phyto/zoo-/bacteria/oxygen	number of FU and SV; relations	Zooplankton: SPmodel/ IBmodel	Processes between pelagos and benthos	HM module; PCB module
NORWECOM	Partly: only two groups	Partly: only POM	Partly: no microbial loop	No: only phy	No	Yes/restricted: no zoobenthos	Yes: HM/PCB modules
GHER	Partly: only two groups	Yes: one DOM	No: only N cycle	Partly: phy/ zoo/ bac sum param.	No	Partly: Very crude parameterisation	No
ECOHAM	No: bulk formulation	Partly: only POM	No: only P cycle	No: only phy	No	Partly: Very crude parameterisation	No
ERSEM	Yes: four groups	Yes	Yes/restricted: coarse resolution	Yes	No	Yes/restricted: large boxes	No
ELISE	Partly: only two groups	Partly: only POM	Partly: no microbial loop	No: only phy	No	Yes/restricted: no zoobenthos	Partly: PCB/Cd under progress
COHERENS	No: bulk formulation	Partly: only POM	No: only N cycle	No: only phy	No	No: only SPM	No
POL3d-ERSEM	Yes: three groups	Yes: one DOM	Yes	Yes	No	Yes: nutrients, POM, zoobenthos	No

Appendix 5 Classification of published MPA population models (Gerber et al., 2003).

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TABLE 1. Classification of published marine reserve models, indicating number of models categorized in each class of model attributes within our taxonomy, general approach and relevant findings, and recommendations for future modeling work on marine reserves.

Model attribute and number of models	Approach and findings	Issues in need of further exploration
Number of species Single species: 33 Multispecies: 1	Including trophic responses likely to reduce efficacy of MPAs	Single-species models may suggest optimistic results; future models should examine effects of multispecies interactions.
Life cycle Explicit reproduction: 22 Single cohort: 12	Single-cohort models allow assessment of effects of reserve, given lack of data on relationship between egg production and recruitment	Need data on recruitment patterns, spatial relationships, and physical oceanography for multigeneration models.
Larval dispersal Expicit dispersal: 7 Larval pool: 23 None: 4	Most models assume simplified mixed larval pool redistributed equally among adult populations	Few models have attempted to consider dispersal of larvae along a coastline explicitly.
Density dependence Predispersal: 8 Postdispersal: 26	Postdispersal density dependence affects recruitment at a particular site while postdispersal dependence can measure effect of density of larvae, adults, or both on recruitment	Predispersal density dependence should be explored in future marine-reserve modeling endeavors.
Population structure Unstructured: 21 Structured: 13	While most models include no population structure, some include age or size structure	Models that do not explicitly incorporate population structure ignore important biological features.
Adult movement Dispersing: 9 Resident: 25	Most models for benthic and intertidal species appropriately assume no dispersal of adults	Adult movement is likely to be important for many marine species and should be incorporated in future models.
Population dynamic Deterministic: 29 Stochastic: 5	Most models include neither process error nor observation error	Models for marine populations should examine effects of stochastic recruitment as well as parameter uncertainty.
Reserve position Permanent: 28 Rotating: 6	Few models have considered effects of rotating spatial harvest on reserve efficacy	Spatial rotation of reserve zones should be considered as a management option in future marine reserve models.

Appendix 6 Theoretical/modelling expertise for policy related questions with regards to Biodiversity at IMARES.

Biodiversity is a metric directly deriving from
- How the interactions between species (food, predation),
- The reaction of species in relation to habitat quality (for temperature), and
- The reaction of species to external forcing factors such as fishing

extrapolate to population dynamics with room for coexistence and persistence of species.

In order to asses the effects of various drivers (such as eutrophication, fisheries and climate change etc) on the biodiversity of marine habitats, it is useful to have models to asses the ecosystem response to changes in these pressures. While "one size-fits all" models such as Ecopath with Ecosim are useful as a general approach to asses changes in ecosystem biomass flows and structure, and resulting derived biodiversity estimates in the long term, this approach falls short for several purposes. We here give a short overview of alternative and complementary approaches within IMARES

Within IMARES, modelling serves to support research in fisheries, ecology, aquaculture and environmental sciences, and therefore constitutes various techniques ranging from (among others) statistical techniques for assessing habitat preferences for Seals (Aarts etc), Food web modelling to assessing coexistence and the population dynamics of fish and benthos (van Kooten, Hille Ris Lambers) Dynamic energy budget modelling of species to assess multistress and populations (Klok) and potential for growth and reproduction in Bivalves (Smaal, Wijsman), Evolutionary models of species change with regard to harvesting induced evolution, and habitat modelling for species distributions.

Not all of these modelling approaches may be directly applicable for purposes of policy driven biodiversity research, yet important techniques in assessing the direction biodiversity of the North Sea may develop, rest on expertise in modelling the relationship between habitat quality and species distribution, species interactions and coexistence, population dynamics and persistence, individual growth in relation to habitat (food and toxicants) quality, and individual behaviour and population growth in relationships to spatial scale and movement and migration, and ecosystem response in relation to external drivers and biomass flows. Ecopath with Ecosim is an example of the last of these approaches.

Table A6 summarized the different modelling approaches in relation to biodiversity applied within IMARES.

Table A6: modelling expertise in relation to biodiversity aspects within IMARES.

Model type	**Time scale**	**Species**	**Data Requirements**	**Examples**	**Usage**
Structured population models	Flexible Long or Short	Few (subject to computational requirements)	Relatively low	Matrix, structured population models	population dynamics and persistence Population viability, population dynamics and conditions for persistence of a species in relation to internal dynamics and external drivers
(Dynamic) Energy budget models	Flexible Long or Short	One, if taking into account interactions, some simplifications may be needed, these then become structured population models.	Relatively high	DEB, COCO[1], EMMY[2]	individual growth in relation to habitat (food and toxicants) quality How species grow metabolize and reproduce, species food requirements, and reproductive output. Also toxicity
Food chain/web models	Flexible Long or Short	In principle	Relatively low	Food web interaction models	species interactions and coexistence Interactions between multiple species and coexistence in relation to internal dynamics and external drivers
Individual based and spatial models	Flexible Long or Short	Small to large depending on assumptions	Relatively low	PROTECT Fish larval transport modelling	individual behaviour and population growth in relationships to spatial scale and movement and migration Spatial interactions between species, dynamic distribution models,
Nutrient Flow models	Flexible Long or Short	Many	Relatively low	ECOWASP ECOSIM	Ecosystem states in relation to external drivers.
Habitat models	No time scale	Many	Relatively high	HABITAT: WL delft	habitat quality and species distribution

[1] *Rueda, J.L., Smaal, A.C. and Scholten H. 2006. A growth model of the cockle (Cerastoderma edule L.) tested in the Oosterschelde estuary (The Netherlands). Journal of Sea Research 54, 276-298.*

[2] *Scholten, H. and Smaal, A.C. 1999. The ecophysiological response of mussel (Mytilus edulis) in mesocosms to a range of inorganic nutrient loads: simulations with the model EMMY. Aquatic Ecology 33:83-100.*

Modelling Approaches

Population viability analysis with structured population models applicable to assess variability status of keystone species or RedList species. To assess the current status and monitor changes towards set policy targets such as the 2010 target, population viability of species should be known accurately. The most authoritative and objective system for classification of population viability was developed by The International Union for the Conservation of Nature's (IUCN). These so called Red List criteria are quantitative, clear-cut, transparent and scientifically sound and therefore avoid subjectivity which by definition is part of expert opinion. The Red List status is based on changes in either observed population size and range or projected population viability using demographic data.

Matrix models can be helpful in projecting population viability. Since several decades matrix models have been applied in conservation. Such models are advantageous because of their low data requirement, direct link with the field data, and clear link between the population growth rate in the model and the demographic parameters.

Examples of structured population models applications in marine species developed by IMARES:

e.g. Birds:

Hemerik, L. and Klok, C. 2006 Conserving declining species: what help can we expect from the use of matrix population models? *Animal Biology* 56: 519-533

Klok, C., Roodbergen, M. and Hemerik L.. 2009. Diagnosing demographic data of declining wader species with a simple matrix model. *Animal Biology* 59: 1-16.

Schröder, S.E., Schobben, J.H.M. and Meininger, P.M. 1996. Een populatiemodel voor de visdief Sterna hirundo. Rapport RIKZ-96.021.

Marine mammals:

Klok, C. and Hemerik, L., in prep. Assessing the conservation status of marine mammals using matrix population models when demographic data are incomplete.

Amoebe species:

Schröder, S.E. and Schobben J.H.M., 1997. Populatiemodellen voor geselecteerde AMOEBE soorten. Werkdocument RIKZ/OS-97.134.

Use of **mechanistic models based on the Dynamic Energy Budget** concept to assess the impact of multi stress (cased by different drivers), or the development of individual species (cockles).

To investigate how different stress factors interact one can conduct experiments in the field and test the joint effect of e.g fisheries and eutrophication Such a study, however, does not give insight in the mechanisms of interaction and is not feasible for long-lived species. Another strategy is to test the combined effects of these stess factors on survival, growth and reproduction of individuals under controlled conditions and extrapolate these effects with population models to assess the impact on population viability. Changes in demographic rates result from changes in the energy budget of an individual. An energy budget model combined with a population model, therefore, is very useful to integrate effects of multiple stress factors. The DEB framework gives insight in the pathways through which stressors change the energy allocation of an individual. With this insight one can predict how stressors interact.

A DEB model for cockles has been developed by IMARES in Yerseke and tested against an extensive dataset for the Oosterschelde. At present DEB models for mussels and Pacific oysters are being developed using the same model formulation. The DEB model for cockles is incorporated into the Delft-3D water quality modelling environment. Compared tot the COCO and EMMY models, the amount of parameters in the DEB model are much less and more generic. The DEB parameters for various (shell)fish species are available within literature (e.g. Van Der Veer *et al.* 2006) and are estimated and updated within the AquaDEB (www.ifremer.fr/aquadeb) in which IMARES participates.

Examples:

Klok, C. 2008. Gaining insight in the interaction of zinc and population density with a combined Dynamic Energy Budget- and population model *Environmental Science and Technology* 42: 8803-8808.

Klok, C., Holmstrup, M. and Damgard, C. 2007. Extending a combined Dynamic Energy Budget matrix population model with a Bayesian approach to assess variation in the intrinsic rate of population increase. *Environmental Toxicology and Chemistry* 26: 2383-2388.

Van Der Veer, H.W., Cardoso, J.F.M.F. and Van Der Meer, J.R. 2006. The estimation of DEB parameters for various Northeast Atlantic bivalve species. *Journal of Sea Research* 56: 107-124.

Use of **food web models** to assess the structure and function of ecosystems

Biodiverstiy is maintained by the processes driving the population dynamics between species. Modelling the interactions between species therefore is an important part of understanding how ecosystem responses to external pressures such as fishing pressures eutrofication (directly manageable) and climate change (not directly manageable), and thus the ways biodiversity responds to these pressures.

Food web models take the interactions between key organisms and/functional groups between organisms and extrapolate how these result in the growth and decline of a population. One can then either theoretically, or numerically calculate species and ecosystem properties such as invasion fitness, resilience and resistance. In addition the exploration of possible regime shifts also becomes possible.

Within IMARES we have broad expertise in modelling species specific interactions and how they extrapolate to coexistence between species.

Examples:

De Roos, A.M., Schellekens, T., van Kooten, T. and Persson, L. 2008. Stage-specific predator species help each other to persist while competing for a single prey. *Proceedings of the National Academy of Sciences of the United States of America* 105(37) pp 13930-13935.

Hille Ris Lambers, R., van de Koppel, J. and Herman, P.M.J. 2006. Persistence despite omnivory: benthic communities and the discrepancy between theory and observation *Oikos*, 113 (1): 23-32.

Hille Ris Lambers, R. and Dieckmann, U. (2003) Competition and predation in simple food webs: intermediately strong trade-offs maximize coexistence. *Proceedings of the Royal Society of London Series B-Biological sciences*, 270 (1533): 2591-2598.

Use of **individual- based**, and **spatial models** to asses the spatial dynamics of ecosystem

When the key interactions between species are spatially based, cellular automata and individually based methods may be more appropriate, specifically when spatial variation in encounter rates between organisms, (and drivers, for example fishers) are of key importance in determining the processes governing population dynamics. Models in this case represent computer code implementations of rules governing birth, growth, death, and migration, and interactions between species. They may either constitute individual reaction to extrinsic drivers (larval transport) or how species interactions and migrations extrapolate to

Examples:

Dekker, W., Deerenberg, C.M., Daan, N., Storbeck, F. and Brinkman, A.G. 2009. Marine Protected Areas and commercial fisheries: the current fishery in potential protected areas, and a modelling study of the impact of protected areas on North Sea Plaice. IMARES report C066/09. Wageningen IMARES, IJmuiden.

Rijnsdorp, A.D. and Pastoors, M.A. 1995. Modelling The Spatial Dynamics And Fisheries Of North-Sea Plaice (Pleuronectes-Platessa L) Based On Tagging Data ICES *Journal Of Marine Science,* 52 (6): 963-980.

Bolle, L.J., Dickey-Collas, M., Erftemeijer, P.L.A., van Beek, J.K.L., Jansen, H.M., Asjes, J., Rijnsdorp, A.D. and Los, H.J. 2005. Transport of Fish Larvae in the Southern North Sea. Impacts of Maasvlakte 2 on the Wadden Sea and North Sea coastal zone. Track 1: Detailed modelling research. Part IV: Fish Larvae. Baseline study MEP Maasvlakte 2. Lot 3b: Fish Larvae IJmuiden: RIVO, (Report / RIVO C072/05) - p. 144.

Use of **nutrient based flow models** for primary production, incorporating biological physical and chemical processes.

These models use detailed rules of biomass flows as a result of species interactions to model primary production in response to external drivers. Within IMARES the EcoWasp ecosystem model has been developed. This is a dynamic model for the integrated simulation of biological, chemical and physical processes in a shallow tidal water system (Brinkman 1993). Biological and chemical key processes such as algae dynamics, zooplankton and zoobenthos dynamics, mineralisation, sorption, pore water, sediment/water exchange and air/water exchange are modelled in detail. The model thus integrates formalised knowledge of ecosystem processes, and, among others, acts as a test of the applicability of sub-study results. A schematic outline of the ecosystem model is given in Figure A6.1. All the mentioned variables and process types can be found in the water column as well as in the sediment. For example: algae processes also run in the deepest sediment layer; although there only loss processes such as mortality are relevant. The computer program determines the constraints, since processes that are not programmed cannot be calculated. On the other hand, processes may be left out of the calculation by setting appropriate switches. The number and the kind of the variables to be calculated may be chosen in a similar way: the choice is free up to the limits set by the program.

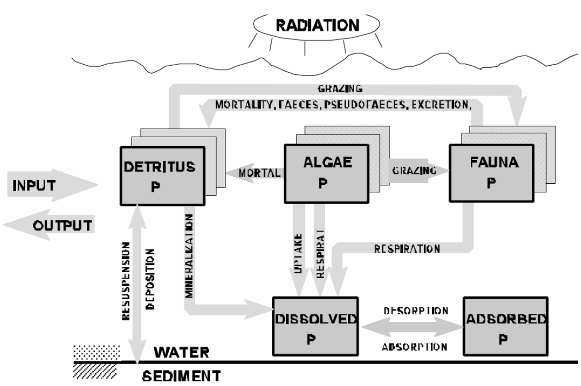

Figure A6.1. Processes and variables implemented in the EcoWasp model. P represents all nutrients

The structure and processes involved with the algae, fauna and detritus model compartments are schematically presented by Figure A6.2. Due to the complexity of the EcoWasp model it could not be truly calibrated, this means that the model needs fine-tuning when a specific situation is modelled. As the model simulates the major marine trophic levels, it can be used in the 'ecosystem' approach of the EMS. The model does need adjustment when pressures resulting from human activities need to be assessed. Possibly, while fine-tuning the model to a specific situation, the parameter that is being affected by human activities can be identified.

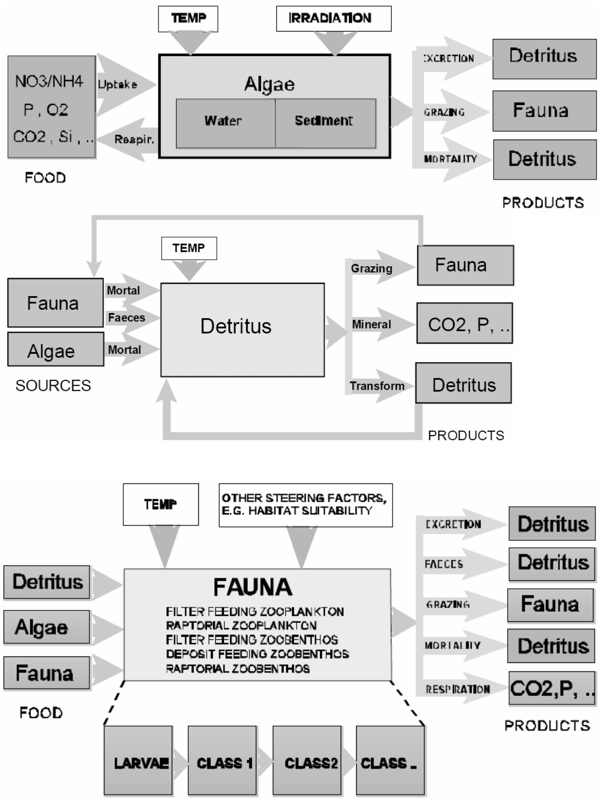

Figure A6.2. Schematic representation of the processes concerning Algae (top-left), Detritus (top-right) and Fauna (bottom) as implemented in EcoWasp

The model has been set up for the western part of the Wadden Sea, in which it distinguishes between 6 spatial cells Figure A6.3. In perspective of the EMS this is favourable, as is discussed earlier in section 3. On the other hand the spatial applicable range of the model is limited as the model can only be applied to shallow tidal systems.

Examples:

Brinkman, A. G. 1993. Biological processes in the EcoWasp ecosystem model. 93/2, Institute for Forestry and Nature Research, Wageningen.

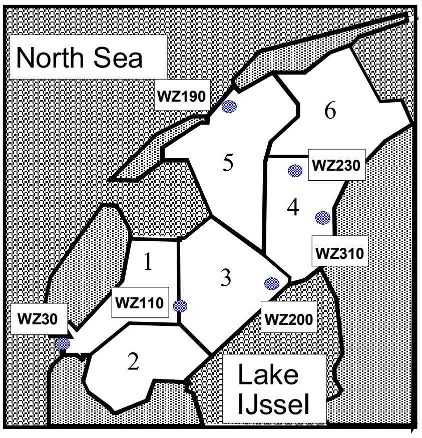

Figure A6.3. Outline of the Wadden Sea as applied in the model setup.

Use of **Habitat models** to asses (potential) species distributions in relation to habitat quality
The suitability of a location for a species is a function of various biotic and abiotic environmental conditions. Habitat models calculate the habitat suitability from the environmental conditions. In essence the habitat suitability is calculated using knowledge rules. These knowledge rules can be based on complex multivariate statistical analysis as has been done for example for cockles in the Oosterschelde (Kater *et al.* 2003, Wijsman 2007) and Westerschelde (Steenbergen & Meesters 2006, Wijsman & Kesteloo 2007) and for Pacific oysters in the Oosterschelde (memo Steenbergen IMARES 2006). Alternatively the knowledge rules can be based on expert judgment (Figure A6.4).

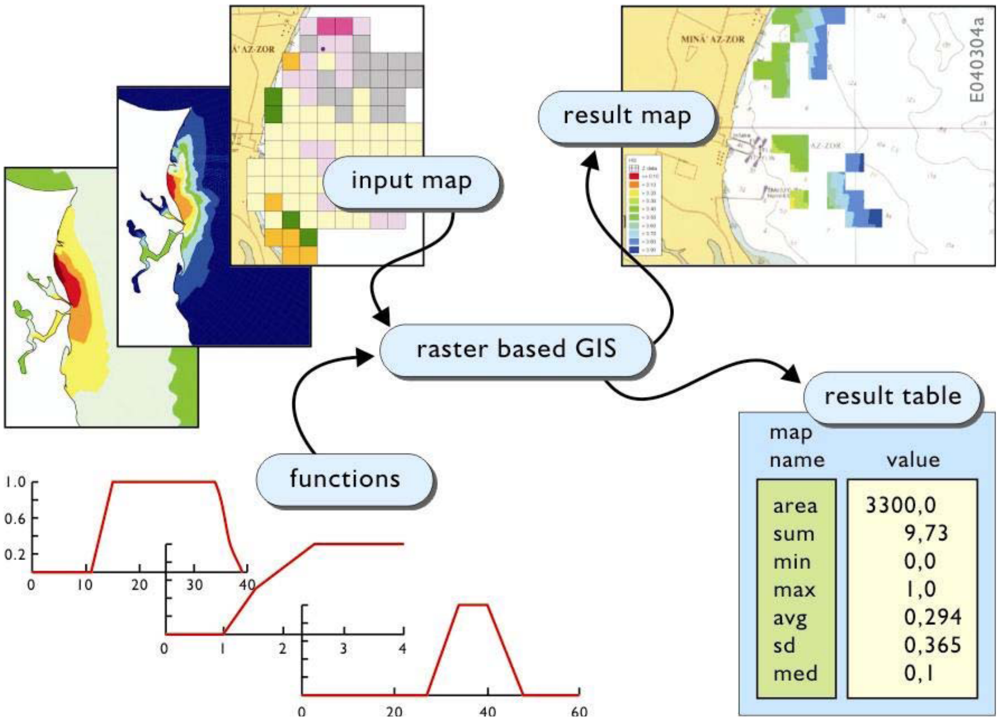

Figure A.6.4. Overview of habitat model. Input maps are combined using knowledge rules (functions) within a GIS. The results are maps indicating the spatial distribution of habitat suitability indices and summarizing tables.

At IMARES have experience with both statistical multivariate habitat models and habitat models based on literature data and expert judgment. IMARES is involved in the development of the GIS tool HABITAT (public.deltares.nl/display/HBTHOME/Home). HABITAT is a GIS-based framework application that allows for the analysis of ecological functioning of study areas in an integrated and flexible way. GIS maps and environmental information, for example resulting from models (e.g. Delft3D) or field observations, are combined to generate spatial (maps) and quantitative (tables) results. HABITAT can be applied to analyze the availability and quality of habitats for individual species. Moreover, it can be used to map spatial ecological units (e.g. ecotopes) and predict spatial changes in habitat suitability for example due to human interventions. By using HABITAT, predefined habitat evaluation models can be used for individual species, or new modules can be defined to suit the need for specific applications. As such, HABITAT is a flexible tool and a strong predictive instrument which can be of great advantage in the case of specific long term planning projects and decision support systems (Wijsman 2003, Wijsman *et al.* 2004, Wijsman & Verhage 2004).

Examples:

Kater, B.J., Geurts van Kessel, A.J.M. and Baars, J.M.D.D. 2006. Distribution of cockles Cerastoderma edule in the Eastern Scheldt: habitat mapping with abiotic variables *Marine Ecology Progress Series* 318, 221 - 227.

Leopold, M.F. and Baptist, M.J. 2007. De effecten van onderwaterzandsuppleties op het habitat van de Kustzee, Spisula en enkle beschermde soorten zeevogels IMARES Rapport C014/07. Wagenibngen IMARES, Texel.

Steenbergen, J. and Meesters, H.W.G. 2006. Habitatmodellen in het beheer: zijn state-fo-the-art modellen voor kokkels in de Westerschelde bruikbaar voor beheer en beleidsbesluiten? IMARES Rapport C091/06. Wageningen IMARES, Yerseke/Den Burg.

Steenbergen, J., Baars, J.M.D.D. and Bult, T.P. 2004. Habitatmodellen voor kokkels in de WesterscheldeIJmuiden : RIVO Rapport C055/04. RIVO, Ijmuiden.

Wijsman, J.W.M. 2003. Verkennende studie voor de validatie van het Zoute wateren EcotopenStelsel (ZES) aan de hand van bodemdiergegevens. Report No. Z3670, WL I Delft Hydraulics, Delft.

Wijsman, J.W.M. 2007. Effecten van zandhonger in de Oosterschelde op kokkels, oesters en de kweek van oesters en mosselen. Report No. C002/07, Wageningen IMARES, Yerseke.

Wijsman, J.W.M. and Kesteloo, J.J. 2007 Het effect van baggerwerkzaamheden t.b.v. de verruiming op de kokkelbestanden in de Westerschelde. Report No. C081/07, Wageningen IMARES, Yerseke.

Wijsman JWM, Thabet RAHA, Odeh M, Ramadan K. and Areiqat, A. 2004. Taweelah B IWPP project. Hydraulic and ecological impact study. Report No. Z3574, WL I Delft Hydraulics, Delft.

Wijsman J.W.M. and Verhage L 2004. Toepassing van het Zoute wateren EcotopenStelsel (ZES) voor de Waddenzee met behulp van HABITAT. Report No. Z3891, WL I Delft Hydraulics, Delft.

Appendix 7 Workshops on the applicability of EwE for PBL questions

A7.1 Introduction

PBL has indicated to have specific interest in the foodweb model Ecopath with Ecosim (EwE). EwE combines software for ecosystem trophic mass balance (biomass and flow) analysis (Ecopath) with a dynamic modelling capability (Ecosim) for exploring past and future impacts of fishing and environmental disturbances. This model system is widely used as a tool for analysis of exploited aquatic ecosystems, having reached 2400 registered users in 120 countries, and leading to in excess of 150 publications (Christensen & Walters, 2004). Lately EwE models were developed to assess marine biodiversity at a global scale (EcoOcean) and applied within COPI (Cost for Policy Inaction) (Braat & ten Brink, 2008).

Ecopath is structurally and empirically based on a trophic mass balance. Model parameters are determined from information on productivity and consumption per unit biomass, as well as fishery removals, for each species in the ecosystem. For many of the species, these will be unknown, and borrowed from other species and systems. This static structure (Ecopath) is then converted to a dynamic system (Ecosim) with the static system as the equilibrium state, and differential equations describing how production rate, consumption rate, and rate of biomass growth of each species depend on each other (Walters *et al.*, 1997). In some cases, the model is unlikely to represent dynamics very far from equilibrium, and will not necessarily behave in the right way when leaving the equilibrium (see caveats in Walters *et al.*, 1997).

Two workshops were organised to discuss the pros and cons of EwE within the scope of application for PBL questions. The first was organised with ecological modellers within IMARES, the second was featured by Steve Mackinson, one of the developers of the North Sea EwE model at Cefas(UK), PBL and IMARES (minutes of both workshops are added below).

The general take home message of these workshops was that the pros of EwE are:

- This model contains a lot of valuable information on feeding relations between fish species or groups;
- The model is already working for the North Sea;
- This current version can be used for policies on fisheries if changes are small;
- The model can be made spatial and therefore is a good instrument to visualize policy action;
- The model has a reasonable user friendly modelling environment;
- Steve Mackinson, one of the developers of the North Sea model in EwE is very open to cooperation, which is indeed a big pro.

The cons can be summarized as follows:

- The current version of the Noth Sea model is parameterized with fish diet data of 1991, this may no longer be reliable for current applications given changes in fish abundances since 1991;
- Change in model structure (by the number of fish groups or addition of other aspects like bentic fauna or nutrients) must be followed by parameterization and calibration which are time consuming activities, apart from the question whether data are available;
- Hydrodynamics are not well included in the model, whereas this aspect is seen as important given transport of larvae, fish and nutrients;

- The spatial scale of the model is set by the input data that come from fishery catch which is given in ICES blocks (50x50km) this spatial scale is not informative if MPAs or windmill parks are the objective in the study;
- Bentic processes are currently not well implemented in the model;
- The model is not tailored for biodiversity assessments, it is especially informative for fish species and other species (e.g. mammals) which are caught by fisheries;
- In the model size structure is not well implemented and therefore fishery policy on size cannot be evaluated by the model;
- It is a strategic instrument, the model output is valuable on relative long term, large special scale (by the way this can also be seen as a pro).

A7.2 Notulen interne workshop in het kader van PBL-project 'voorstudie modelinstrumentarium' 20 oktober 2008

Aanwezig: Chris Klok, Erik Meesters, John Schobben, Niels Hintzen, Pepijn de Vries, Ralf van Hal, Reinier Hille Ris Lambers, Tobias van Kooten
Afwezig: Adriaan Rijnsdorp, Bert Brinkman, Gerjan Piet, Willem Dekker
Voorzitter: John
Notulist: Pepijn

Daar waar gesproken wordt over 'het model' wordt gedoeld op het model van Mackinson *et al.* Dit is een ecosysteemmodel van de Noordzee dat geïmplementeerd is in Ecopath/Ecosim (www.ecopath.org). Ecopath is een statisch ecosysteemmodel dat is gebruikt voor parameterisering van de dynamische Ecosim-module. Ruimtelijke differentiatie is tot slot geïmplementeerd in Ecopath. Deze processen zijn schematisch weergegeven in figuur A7.1.

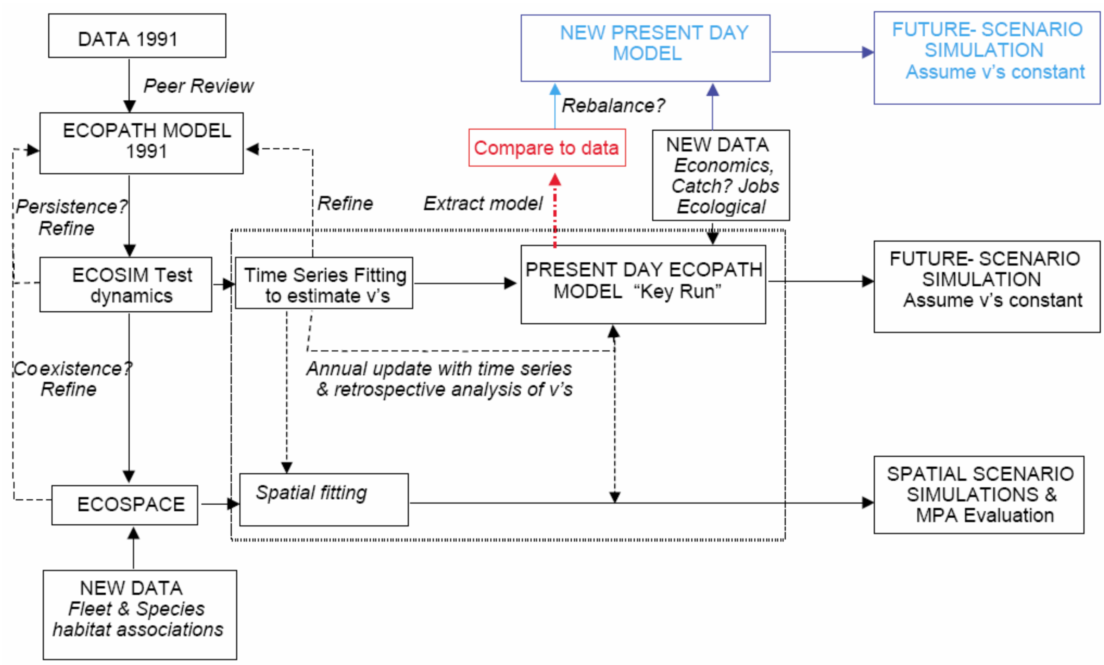

Figure A7.1. Schematische weergave van de werkwijze van het samenstellen en testen van het Noordzee-model van Mackinson et al.

Discussie over modelaannames

- Het model laat hydrodynamica buiten beschouwing. Hydrodynamica is echter een belangrijke factor bij onder andere eutrofiëring (stoftransport) en (vis)larventransport.
- In het model is biomassa de sturende factor bij populatieontwikkeling.
  - Verstoringen in het systeem (zoals bij voorbeeld El Niño) spelen hierdoor geen rol in het model. Dit zou meegenomen kunnen worden door specifieke parameters in het model tijdsafhankelijk te maken.
  - Effecten van toxicanten zijn niet per se biomassagestuurd. Effecten van toxicanten zijn meestal soortspecifiek en daardoor niet in te schatten voor functionele groepen.
  - In het model kunnen soorten niet uitsterven (dat wil zeggen de biomassa is altijd groter dan 0). De kans op uitsterven is echter wel relevant voor Rode Lijst soorten alsmede invasieve soorten. Wel biedt een afname in het model van biomassa onder een bepaalde drempelwaarde aanknopingspunten voor nader onderzoek. Het

toevoegen van zeldzame soorten aan het model zal lastig zijn omdat slechts een kleine bijdrage leveren aan de biomassa stromen en bovendien data ontbreken omdat deze soorten vaak niet (mogen) worden gemonitord.
    - Het model rekent met biomassa's van functionele groepen en individuele soorten i.h.g.v. voor de visserij interessante soorten, er zal dus nog een vertaalslag moeten worden gemaakt naar biodiversiteit (soortsaantallen).
- Eutrofiëring wordt niet in detail gemodelleerd, primaire productiviteit wordt als 'hard' getal ingevoerd (gebaseerd op jaargemiddelden) en niet dynamisch gemodelleerd. Effecten van eutrofiëring kunnen alleen indirect via verandering in het voedselaanbod worden afgeleid.

- Ecopath wordt geparameteriseerd met behulp van een steady-state aanname waarbij de gemiddelde toestand van het systeem wordt gebruikt om het model te kalibreren.
    - Het model is hierdoor ongeschikt om uitspraken te doen op korte termijn. Het model is er met name gericht op om uitspraken te doen over trends op langere termijn.
- De modelparameters zijn gekalibreerd voor een specifieke situatie. Daarmee zijn met name de parameters waar weinig van bekend is afgesteld.
    - Het model zou moeten worden toegepast om uitspraken te kunnen doen bij een ingreep in het systeem, waarbij de toestand verandert. Echter het model is gekalibreerd voor een specifieke toestand en is in principe alleen geldig voor die toestand. Voor elke andere toestand zou het model opnieuw geparameteriseerd/gekalibreerd moeten worden. Het model kan wel gebruikt worden om trends ten opzichte van de toestand waarop het gekalibreerd is te bepalen.
- Het model is deterministisch (relaties tussen variabelen liggen vast). Hoewel een stochastische benadering meer informatie zou kunnen verschaffen over de onzekerheid in het model zal het niet leiden tot een beter beeld/begrip van het systeem.

Geschiktheid van het model in kader van beleid
- Visserijquota's
    - Naar verwachting zal het relatief weinig moeite kosten om het model dusdanig aan te passen om uitspraken te doen over effecten van visserijquota's. Wellicht dat het volstaat om de visserijmortaliteit als parameter van de betreffende soorten aan te passen. Ook de mortaliteit van niet target-soorten (bijvangst) zal daarbij bekend moeten zijn.
- Beleid gericht op maaswijdte/lengte vis
    - Het model maakt momenteel slechts voor enkele vissoorten onderscheid tussen verschillende klassen (juveniel/adult). In het model is dit leeftijdsgebonden. Echter, in de meeste vissen is het halen van het volwassen stadium niet bepaald door leeftijd maar door grootte, en deze laatste wordt weer bepaald door factoren als voedselbeschikbaarheid. Om uitspraken over de effecten van maaswijdte te kunnen doen is daarom inzicht noodzakelijk in de age/size relatie.
- Gesloten/beschermde gebieden (MPA's)
    - Het onderliggende Ecospace-model hanteert momenteel zeer grote spatiële gridcellen. Hierdoor kan het model op dit moment alleen uitspraak doen over grote gebieden. Hoewel het technisch mogelijk is om de ruimtelijke resolutie te vergroten, is het niet de verwachting dat de voorspellende kracht van het model daarmee toeneemt. Ook zullen de locaties van bijvoorbeeld paaigebieden een rol spelen bij de keuze van een MPA. Momenteel houdt het model hier geen rekening mee. Wellicht dat het model gekoppeld kan worden met GIS-kaarten om een evenwichtiger beeld te geven.

- Aanleg/gebruik windmolen park
  - Ook hier speelt de ruimtelijk schaal een rol. De ruimtelijke resolutie is op dit moment te laag om iets zinnigs te kunnen zeggen over de effecten van het aanleg/gebruik van windmolen parken. Hoewel er modellen zijn die rekenen aan effecten van windmolenparken (bijv. CUMULEO), doen deze modellen doorgaans geen uitspraak over biodiversiteit.
- Maatregelen t.a.v. bodemberoerende visserij
  - Hoewel de impact van bodemberoerende visserij waarschijnlijk relatief simpel is in te brengen in het model, zal de benthos met name worden beïnvloed door deze vorm van visserij. De benthos is in het model echter zeer algemeen beschreven. Er wordt in het model alleen onderscheid gemaakt tussen de volgende bethische ongewervelden: Infaunal macrobenthos, Small infauna (polychaetes), Epifaunal macrobenthos (mobile grazers), Small mobile epifauna (swarming crustaceans), Sessile epifauna. Voedselwebrelaties van de benthische gemeenschap zijn niet goed bekend, dit is ook één van de redenen waarom deze algemeen zijn gehouden in het model. Dit betekent ook dat het niet eenvoudig zal zijn om de algemene groepen in het model verder op te splitsen. Aangeraden wordt om effecten van bodemberoering met een ander model te beoordelen.
- Maatregelen omtrent eutrofiëring
  - De relatie tussen algen en benthos bleek lastig te calibreren in het model: de consumptie van benthos bleek in eerste instantie te worden overschat. Hierdoor wordt het lastig om uitspraken te doen over effecten van eutrofiëring.
  - Timing is ook een aspect dat niet in het model lijkt te worden beschouwd. Belangrijke indicatoren zijn bijvoorbeeld wanneer algenbloei optreedt en hoe uitgebreid ze plaatsvindt is en hoe lang deze duurt. Dergelijke seizoensfluctuaties worden door het model niet gesimuleerd.

Kan het model uitspraken doen over de volgende indicatoren?

- Natuurwaarde. Het begrip “natuurwaarde” is oorspronkelijk ontwikkeld voor terristische biodiversiteit. De natuurwaarde wordt uitgedrukt als de kwaliteit en kwantiteit van een aantal indicatoren. De kwaliteit wordt uitgedrukt als de relatieve toestand (meestal abundantie van soorten) van een soort ten opzichte van een referentiesituatie. De kwantiteit wordt gegeven door het oppervlak van een ecosysteemtype. Voor de zoute wateren is de indicator nog in ontwikkeling en heeft nog geen officiële status.
  - De keuze van de referentiesituatie is vaak punt van discussie. Echter, de referentie zou ook arbitrair kunnen worden gekozen (bijv. huidige parameterisatietoestand van het model), zodat in ieder geval de trend ten gevolge van bepaalde maatregelen kan worden bepaald.
  - Veel van de soorten die momenteel zijn voorgesteld voor het bepalen van de mariene natuurwaarde worden niet expliciet door het model gesimuleerd. Er is los van de workshop een overzicht gemaakt van voorgestelde soorten voor de mariene natuurwaarde en de beschikbaarheid in het model. Het model maakt met name onderscheid tussen verschillende vissoorten, maar in mindere mate tussen zoogdieren en ongewervelde benthos. In zeevogels wordt geen onderscheid in soorten gemaakt, deze wordt als gehele groep beschreven door het model. Het is niet wenselijk om soorten te introduceren in het model. Dit betekent namelijk dat het gehele model opnieuw geparameteriseerd moet worden. Bovendien wordt het model beschouwd als een gesloten system. Voor vogels is het veelal zo dat zij bijvoorbeeld elders broeden. Het zal hierdoor niet mogelijk zijn om specifieke vogels goed te modeleren in dit gesloten systeem. Wel kan het model worden gebruikt om voedselbeschikbaarheid te berekenen voor vogels. Vervolgens zal voor specifieke soorten de viability met populatie modellen moeten worden bepaald.

- Soortgroep trend index. De Soortgroep Trend Index (STI) beschrijft de trend van afzonderlijke soortgroepen of deelsets daarvan vanaf een vast vergelijkingsjaar (Ten Brink *et al.* 2000, De Heer *et al.* 2005). De beoordelingsgrondslag van de Soortgroep Trend Index is, anders dan bij de Natuurwaarde niet 'natuurlijkheid' maar 'hoe meer (van een bepaalde groep) hoe hoger'. Het geeft een beeld van de ontwikkelingen van bepaalde selecties uit het ecosysteem, bijvoorbeeld, zoogdieren, carnivoren of economisch relevante soorten.
    - De selectie van soorten en soortgroepen ligt niet vast voor de STI. Dit betekent dat de selectie kan worden aangepast aan de beschikbaarheid van soorten/soortgroepen in het model. De STI wordt per (functionele) groep berekend en kan alleen worden vergeleken als voor iedere groep hetzelfde referentiejaar wordt gehanteerd. Het model moet (met de eerder aangegeven beperkingen) in staat zijn om de STI te berekenen voor de soorten/soortgroepen die zijn geïmplementeerd.
- Rode Lijst indicator. De Rode Lijst Indicator (RLI) geeft een beeld van die soorten die met uitsterven bedreigd worden. Rode Lijsten geven de kwetsbaarheid van soorten aan.
    - Gegeven het feit dat een soort op de Rode Lijst is geplaatst kan worden aangenomen dat de soort zeldzaam is en daardoor slechts een geringe invloed heeft op de biomassa stromen in het voedselwebmodel.
    - Slechts een beperkt aantal Rode lijst soorten (mn vissen) zijn expliciet meegenomen in het model.
    - Met het model kan wel de voedselbeschikbaarheid voor een aantal Rode Lijst soorten worden bepaald.

Een algemene kanttekening bij de beschouwde indicatoren is dat ze geen informatie over de structuur van het ecosysteem verschaffen.

Welke vragen kunnen hoe makkelijk worden beantwoord met het model?

Er wordt onderscheid gemaakt tussen vijf verschillende categorieën welke afzonderlijk zijn behandeld:

1. Het model is direct toepasbaar zonder aanpassingen
    - Eigenlijk is het model voor geen enkele toepassing direct van de plank te gebruiken. De auteurs erkennen dit zelf ook, ze geven onder andere het volgende aan: 'If we were to fit the model to fewer groups, then the fits could be improved and thus we advise strongly that the model should be tailor fit to specific data depending on the purpose of the application.'
2. Het model is toepasbaar met een aantal kleine aanpassingen
    - Met kleine aanpassingen is het model sowieso geschikt voor het doel waarvoor het model ook is ontwikkeld. Namelijk: ter ondersteuning van een ecosysteembenadering voor visserijmanagement. Het model richt zich daarom ook met name op vis. Met name rekenen aan quota's zal relatief weinig moeite kosten.
3. Het model is toepasbaar met grote aanpassingen
    - Andere mogelijke maatregelen bij het visserijbeleid (bijv., MPA's, ander vistuig/maaswijdte) zullen meer aanpassingen vergen. Bij MPA's worden problemen verwacht met de ruimtelijke resolutie van het model, zoals eerder beschreven. Bij aanpassing van vistuig is het van belang voldoende te weten over de selectiviteit van het tuig voor alle soorten. Dit is doorgaans niet bekend.
4. Het model is niet goed toepasbaar, er zijn echter geen alternatieven
    - Eigenlijk zijn er altijd wel alternatieven beschikbaar. Echter een aantal alternatieven zal wel veel inspanning vereisen om werkbaar te maken.

5. Het model is niet goed toepasbaar, er zijn wel alternatieven
    - Zoals eerder aangegeven richt het model zich met name op visserij-management. Voor andere activiteiten (bijv. aanleg/gebruik windmolenpark, exploratie/winning olie/gas, etc.) is het model minder geschikt. Verder is het model niet direct geschikt om uitspraken te doen over de biodiversiteit van bepaalde groepen, waaronder: vogels, zeezoogdieren en benthos. Het model kan wel als basis dienen om bijvoorbeeld voedselbeschikbaarheid te berekenen. Voor specifieke soorten zullen afzonderlijke, of gekoppelde populatiemodellen moeten worden toegepast. Voor de Maasvlakte is al gerekend aan effecten op biodiversiteit voor benthos. Ook kan een model als EcoWasp van Bert Brinkman wellicht uitkomst bieden, als een vertaalslag van de Waddenzee, naar de Noordzee mogelijk blijkt, of andere dynamische ecosysteemmodellen, waaronder zogenaamde "size-spectrum" modellen. Daarnaast kunnen habitatgeschiktheidsmodellen worden gebruikt om uitspraken te doen over biodiversiteit van benthos. Al moet gezegd worden dat weinig bekend is over de voedselwebrelaties van specifieke benthos-soorten, waardoor het allicht noodzakelijk is om biodiversiteit voor benthos moet bepalen aan de hand van (algemene) functionele groepen als proxy voor de biodiversiteit van de soorten. Voor alternatieven voor zoogdieren en vogels zullen experts op dat gebied geraadpleegd moeten worden.

Algemene aanbevelingen:

In het algemeen kan worden gesteld dat het model met name geschikt is om uitspraak te doen over trends op een grote tijd- en ruimtelijke schaal. Daarbij richt het model zich met name op vissoorten. Omdat het model de Noordzee ecosysteembreed beschrijft waarbij voor alle onderdelen (behalve op nutriëntniveau) de massabalansen kloppend zijn (een 'ecosysteembenadering" dus), kan het inzicht verschaffen in 'onverwachte' of contra-intuïtieve processen in het ecosysteem, echter het is zeer aan te raden om d.m.v. vergelijking met andere, ecosysteem modellen de robuustheid van de ecopath model uitkomsten te toetsen op bijvoorbeeld realistischere aannames over grootte structuur, kortere tijdschalen, hogere spatiele resolutie, etc.

Daarnaast moet niet van het model verwacht worden dat het (mede) antwoord geeft op allerlei vragen waarvoor het model niet ontworpen is. In een aantal gevallen is misschien een afgeleid kenmerk te vinden dat gekoppeld kan worden aan de gestelde vraag (bijvoorbeeld over biodiversiteit), maar het is waarschijnlijk weinig zinvol om in het model zélf veel te veranderen om zo'n biodiversiteitsindex te produceren (of iets soortgelijks, biodiversiteit is hier als voorbeeld gebruikt). In veel gevallen zal het zinvoller zijn aparte modellen te ontwerpen die toegespitst zijn op de betreffende vraagstelling. Afhankelijk van die vraagstelling kan mogelijk wel van EcoPath/EcoSim-uitkomsten gebruik worden gemaakt, maar dat wordt dan per geval bekeken.

Het is aan te raden modeluitkomsten aan te vullen met expert opinion(s). Daarnaast kunnen modelberekeningen op basis van 'worst case'-aannames worden uitgevoerd (eventueel met zekerheidsgrenzen), om aan te geven wat in het slechtste geval de trend zou zijn. Het is bovendien nuttig om modelberekeningen te houden naast resultaten van eenvoudigere (meta)modellen, om te zien of beide modellen vergelijkbare resultaten genereren.

A7.3 'Workshop modelling instruments for marine biodiversity policy' 17th November 2008

Minutes

Present:
IMARES

- Chris Klok
- Reinier Hille Ris Lambers
- Tobias van Kooten
- Bert Brinkman
- Adriaan Rijnsdorp
- Charlotte Saull (minutes)

CEFAS

- Steve Mackinson

PBL

- Rick Wortelboer
- Paul Westerbeek

Opening and welcome by Chris Klok.

Introduction of all participants

Presentation given by Rick Wortelboer .

Presentation given by Steve Mackinson explaining model Ecopath-Ecosim-Ecospace.

Presentation given by Bert Brinkman on Model for the WaddenSea showing the importance/impact of including nutrients in the model.

<u>Discussion outcome:</u>

- Pin down the questions that you want to answer with this model (clarification on objective and questions)
- This model lacks spatial dynamics for specific questions, but could be used to answer parts of specific questions
- Plans to couple Ecospace with MARXAN
- Essential to fully explain mortality of species
- Biodiversity not included in the model, no current plans to do so in the future at this point in time although very important
- Useful model to compare with others (e.g. fishspectrum, SMS, sizebase and MIES) and also with model special dynamics of one species, predator prey models and maybe Ecowasp
- Yes, Ecopath-Ecosim is a useful model for answering some of our questions
- Special resolution is set by data and there are possibilities introduce e.g. nutrients
- Does the timescale fit?
- Model has fast running time
- At the moment it is possible to use the model as it is, no parameterization or major adaption needed

Feedback from internal workshop 20th of October on feasibility North Sea model for PBL use

Strengths:

Model is developed to assess impact of fisheries on fish based ecosystem

Model based on mass balances

Model results specifically valuable for relative large time and space scales

Thus applicable for strategic management questions

Weaknesses

Model is calibrated for certain conditions (steady state) difficult to extrapolate

Hydrodynamics plays an unimportant role

Bentic component highly uncertain in model

Effect assessment of short term and small scale disturbances is low

WAGENINGEN UR For quality of life — Chris Klok — Wageningen IMARES

Weaknesses & Strengths

- Food is the main driver.
- Size structure mostly absent
- Recruitment patterns difficult to model
- Not a population dynamics model
- Structure and parameters effects on model certainty
- Time and space scale – medium to long term over large areas
- Policy screening tool – not tactical implementation
- Mass-balance for initialisation

- Whole ecosystem model
- Complementary with other approaches
- Tested continuously –global users
- Useful accounting tool bringing together readily available data
- Tuned to time series data
- Can be made spatial
- Includes socio-economic considerations in policy evaluation

WAGENINGEN UR For quality of life — Steven Mackinson Cefas — Wageningen IMARES

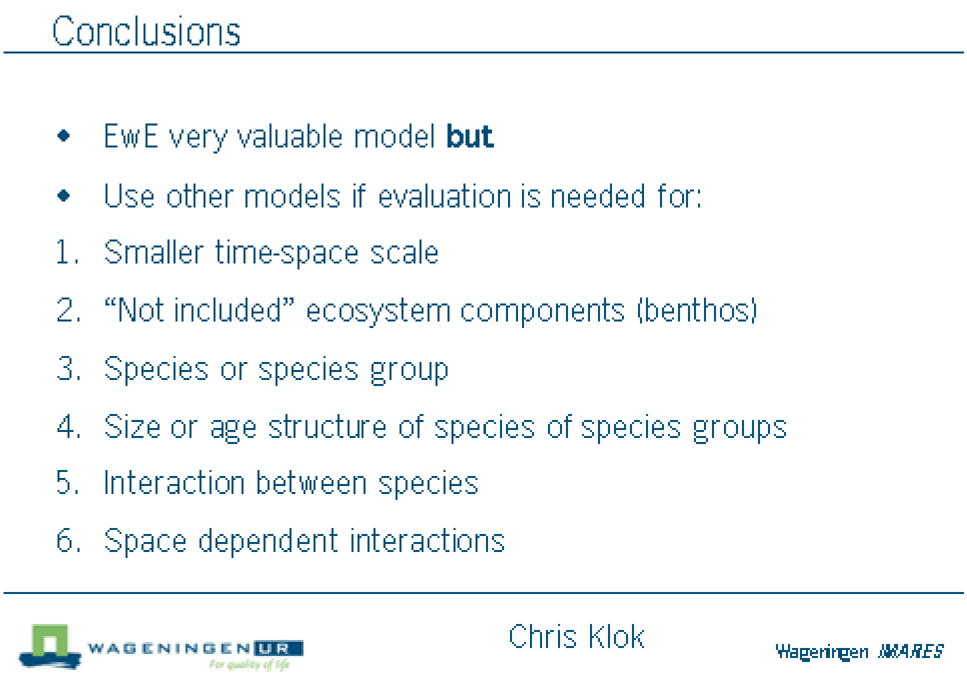

Figure A7.2 Slides from the 2nd workshop.

Verschenen documenten in de reeks Werkdocumenten van de Wettelijke Onderzoekstaken Natuur & Milieu vanaf 2007

Werkdocumenten zijn verkrijgbaar bij het secretariaat van Unit Wettelijke Onderzoekstaken Natuur & Milieu, te Wageningen. T 0317 – 48 54 71; F 0317 – 41 90 00; E info.wnm@wur.nl
De werkdocumenten zijn ook te downloaden via de WOt-website www.wotnatuurenmilieu.wur.nl

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47 *Ten Berge, H.F.M., A.M. van Dam, B.H. Janssen & G.L. Velthof.* Mestbeleid en bodemvruchtbaarheid in de Duin- en Bollenstreek; Advies van de CDM-werkgroep Mestbeleid en Bodemvruchtbaarheid in de Duin- en Bollenstreek

48 *Kruit, J. & I.E. Salverda*. Spiegeltje, spiegeltje aan de muur, valt er iets te leren van een andere plannings-cultuur?

49 *Rijk, P.J., E.J. Bos & E.S. van Leeuwen.* Nieuwe activiteiten in het landelijk gebied. Een verkennende studie naar natuur en landschap als vestigingsfactor

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53.11 *Gaaff, A. & R.W. Verburg.* Indicators for the 'Convention on Biodiversity 2010' Government expenditure on land acquisition and nature development for the National Ecological Network (EHS) and expenditure for international biodiversity projects

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115 *Leneman, H., J. Vader, L.H.G. Slangen, K.H.M. Bommel, N.B.P. Polman, M.W.M. van der Elst & C. Mijnders.* Groene diensten in Nationale Landschappen- Potenties bij een veranderende landbouw,
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