Estuarine, Coastal and Shelf Science xxx (2015) 1–8

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss

# Defining scenarios of future vectors of change in marine life and associated economic sectors

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ARTICLE INFO

*Article history:*
Received 3 May 2015
Received in revised form
14 October 2015
Accepted 17 October 2015
Available online xxx

*Keywords:*
Climatic changes
Socioeconomic aspects
International policy
Ecosystem management
Scenarios

ABSTRACT

Addressing the multitude of challenges in marine policy requires an integrated approach that considers the multitude of drivers, pressures, and interests, from several disciplinary angles. Scenarios are needed to harmonise the analyses of different components of the marine system, and to deal with the uncertainty and complexity of the societal and biogeophysical dynamics in the system. This study considers a set of socio-economic scenarios to (1) explore possible futures in relation to marine invasive species, outbreak forming species, and gradual changes in species distribution and productivity; and (2) harmonise the projection modelling performed within associated studies. The exercise demonstrates that developing interdisciplinary scenarios as developed in this study is particularly complicated due to (1) the wide variety in endogeneity or exogeneity of variables in the different analyses involved; (2) the dual role of policy decisions as variables in a scenario or decisions to be evaluated and compared to other decisions; and (3) the substantial difference in time scale between societal and physical drivers.


## 1. Introduction

Marine ecosystems are affected by a host of anthropogenic pressures, including climate change, ocean acidification, nutrient discharges, intensive fishing pressure and introduction of invasive alien species (Halpern et al., 2008). Each of these poses risks and hazards to the marine environment, its users and society at large (Elliott et al., 2014). Addressing these challenges simultaneously requires an integrated approach that considers the multitude of drivers, pressures, and interests from several disciplinary angles (Pikitch et al., 2004; Schindler and Hilborn, 2015). Likewise, *ex-ante* policy evaluations, considering a wide variety of possible futures, require the development of integrated multidisciplinary scenarios. Integrated marine management then requires that stakeholder views and conflict resolution, governance mechanisms, risk analysis and risk management and measures to fulfil the Ecosystem Approach to Fisheries Management (Pikitch et al., 2004) are all combined (Elliott, 2014).

The EU VECTORS project was part of the 'Oceans of Tomorrow' initiative and was designed to analyse the ecological, environmental and societal consequences of introduction of marine invasive species, outbreak forming species, and gradual changes in species distribution and productivity. The accompanying research focussed on possible trends in major global drivers such as climate change, economic development, and human population growth, and how these interact with a host of regional anthropogenic pressures in the marine environment. In this context, pressures are regarded as the mechanisms emanating from human activities such that, unless mitigation measures are implemented, those activities will lead to state changes and impacts on society. In EU waters,

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http://dx.doi.org/10.1016/j.ecss.2015.10.020
0272-7714/

those pressures include, for example, changes in the magnitude of maritime shipping, the extent of areas designated for offshore wind farms or marine protected areas, the release of land-based pollutants, and amount of income generated from tourism to coastal and marine areas. Hence the management of these pressures requires an integration of both natural (ecology, biogeochemistry, oceanography) and social (economics, governance, policy) sciences (Elliott, 2013).

The multifaceted nature of the relationship between human society and European marine environments and ecosystems has necessitated the adoption of many interlinked pieces of legislation and administrative mechanisms (Boyes and Elliott, 2014). In turn, these are being combined into the EU Integrated Maritime Policy. The revised Common Fisheries Policy (CFP) (EU, 2013), a pillar of this strategy, aims to ensure that fishing practices are environmentally, economically and socially sustainable, and that they provide a sufficient source of healthy food for citizens throughout Europe in the long term. The environmental pillar of the Integrated Maritime Policy is the Marine Strategy Framework Directive (MSFD) (EU, 2008), which aims to more effectively protect the marine environment, and to implement an 'ecosystem approach' to the management of all human activities in the sea with the goal to enable the sustainable use of living marine resources and to ensure the marine environment is safeguarded for future use (Borja et al., 2013). Most recently, the EU Maritime Spatial Planning Directive aims to ensure that marine developments can be planned and managed but within a sustainable marine management system (EC, 2014).

The marine system will change not only due to anthropogenic pressures operating within an area, but also due to the prevailing socio-geopolitical environment and also external factors such as climate change. Hence the challenge in management is to incorporate these interacting factors and scenarios. Harmonising the different analyses and future projections for different components of the marine system necessitates a degree of agreement on how aspects of socio-economic as well as biogeochemical and ecological components of regional seas will change in the future. This study considers a set of socio-economic scenarios to (1) explore possible futures in relation to marine invasive species, outbreak forming species, and gradual changes in species distribution and productivity, and (2) harmonise the projection modelling performed within associated studies (Groeneveld et al., Submitted; Kay and Butenschön, Submitted; Stolte et al., Submitted).

Examples of policy domains where scenarios are typically applied include: climate policy (Nakićenović, 2000; Nakićenović et al., 2000; Moss et al., 2010); landscape planning (Brand et al., 2013; Hirschi et al., 2013); but also marine policy (Haward et al., 2013; van Hoof et al., 2014). Börjeson et al. (2006) provides a valuable typology of scenarios by distinguishing among predictive, explorative, and normative scenarios. Predictive scenarios aim to provide the most likely outcome of an uncertain process, whether or not conditional on a policy. Hence, they are most suitable for tactical decisions that deal with the foreseeable future. Explorative scenarios are designed to examine the range of possible outcomes of an uncertain future. Unlike predictive scenarios, which focus on the most likely outcome, explorative scenarios deal with the range of possible outcomes. To paraphrase Börjeson et al. (2006), predictive scenarios are directed at the question "what *will* happen?", whereas explorative scenarios are directed at the question "what *can* happen?" Lastly, normative scenarios focus on how a prespecified target can be reached.

The current assessment is carried out against a background of highly complex issues, involving many stakeholders and activities, and the need to approach these issues from a trans-disciplinary perspective. This complexity renders the common approaches to uncertainty analysis inadequate: there are simply too many variables involved, and too many interlinkages between them, for a Worst-Case Analysis or a Monte-Carlo Analysis. Moreover, the approach suggested here aims to facilitate strategic rather than tactical policy decisions, dealing with a time horizon over which many developments are highly uncertain. Therefore, in Börjeson et al.'s (2006) typology, the scenarios developed and discussed here are explorative scenarios, dealing with a set of alternative possible futures.

This article presents the scenarios developed within the VECTORS programme, and considers the way in which they were derived and the issues that had to be overcome to specify them. The article is organised as follows. The following section explains the general approach in the development of the scenarios. Section 3 presents the quantified developments in key variables as assumed in the scenarios. Section 4 concludes with the main observations and lessons learnt from the process of scenario development.

## 2. Developing scenarios for the marine environment

The wealth of experience suggests that there is no single, strategically best way to work with scenarios (Pinnegar et al., 2006). However, well-designed explorative scenarios do seem to share some common features including: (1) scenarios are best created through a collaborative process that takes into account the necessary expertise across disciplines; (2) the time horizon is sufficiently distant that the future situation is uncertain; (3) the scenarios are credible in the sense that those involved should be able to imagine living in such a future world; (4) scenarios are internally consistent whereby social, political, economic, environmental, technical and cultural features are well dovetailed in terms of their individual magnitudes and trajectories of change; (5) scenarios are focused on conceptualising a few key features or events which are of prime concern; (6) scenarios do not merely represent a single view of the future but plural views; (7) scenarios are often striking and sometimes uncomfortable with the objective of startling managers so that they become engaged and excited about the findings; (8) good scenarios are dramatised in various ways, i.e. brought to life by scene-setting, stories, case-studies metaphors or encapsulated in memorable and vivid catch-phrases, and (9) good scenarios lead to outcomes that at least test and may help change preconceived visions or plans. Following these guidelines, the scenarios developed in VECTORS were discussed extensively in plenary VECTORS meetings to discuss their consistency from different disciplinary angles, and formulated as two different scenarios describing alternative possible realisations of the future.

The VECTORS scenarios are built on earlier scenario development exercises, notably the SRES (Special Report on Emissions Scenarios) socio-political storylines used by the IPCC (Intergovernmental Panel on Climate Change) (Nakićenović et al., 2000). However they also encompass subsequent studies that have focused explicitly on the marine environment and maritime industries, such as the AFMEC (Alternative Future Scenarios for Marine Ecosystems) (Pinnegar et al., 2006) developed in the United Kingdom, and those developed under the EU research project ELME (European Lifestyles and Marine Ecosystems) (Langmead et al., 2007).

The SRES scenarios follow a four-quadrant approach, whereby the future 'possibility space' is divided into two axes or dimensions (Fig. 1). The basis of the four-quadrant model involves the identification of the two driving forces with the greatest importance and the highest uncertainty. Many existing scenario exercises, whether coincidentally or not, have chosen similar criteria to define their 'possibility space', with an axis representing 'local to global' and an

Please cite this article in press as: Groeneveld, R.A., et al., Defining scenarios of future vectors of change in marine life and associated economic sectors, Estuarine, Coastal and Shelf Science (2015), http://dx.doi.org/10.1016/j.ecss.2015.10.020