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On the role of visualisation in fisheries management

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ABSTRACT

Environmental change has focused the attention of scientists, policy makers and the wider public on the uncertainty inherent in interactions between people and the environment. Governance in fisheries is required to involve stakeholder participation and to be more inclusive in its remit, which is no longer limited to ensuring a maximum sustainable yield from a single stock but considers species and habitat interactions, as well as social and economic issues. The increase in scope, complexity and awareness of uncertainty in fisheries management has brought methodological and institutional changes throughout the world. Progress towards comprehensive, explicit and participatory risk management in fisheries depends on effective communication. Graphic design and data visualisation have been underused in fisheries for communicating science to a wider range of stakeholders. In this paper, some of the general aspects of designing visualisations of modelling results are discussed and illustrated with examples from the EU funded MYFISH project. These infographics were tested in stakeholder workshops, and improved through feedback from that process. It is desirable to convey not just modelling results but a sense of how reliable various models are. A survey was developed to judge reliability of different components of fisheries modelling: the quality of data, the quality of knowledge, model validation efforts, and robustness to key uncertainties. The results of these surveys were visualized for ten different models, and presented alongside the main case study.

1. Introduction

In 2014 McInerny et al. [1] called upon scientists across disciplines to rethink the role of visualisation in their work, to engage users and to avoid bias. They argue that visualisation and graphics are powerful tools for communication upon which the success of the relationship between science, policy and wider stakeholders depends. They highlight the current gap in expertise, knowledge and skills related to design and called for development and adoption of better standards for communication both within academia and to outside audiences. This paper describes recent efforts within an EU funded project, MYFISH (http://www.myfishproject.eu/), to improve the use of visualisation in fisheries management.

MYFISH was a project developed through interactions between stakeholders and scientists. Its broad objectives were to discover alternative goals of fishery management, to build models to explore management options and to communicate modelling outcomes effectively to decision makers and stakeholders. This project illustrates a trend in the governance of fisheries to become more open to stakeholder participation.

Within MYFISH there were several regional case studies, which used various types of mathematical models to assess trade-offs under different management options. MYFISH case studies covered the main areas of European fisheries: the North Sea, the Baltic Sea, the Mediterranean Sea and Western Waters that included the Celtic Sea, the Irish Sea, Bay of Biscay and Iberian Sea. In these regions, and globally, the management practices in fisheries have expanded from a focus on yield or surplus production for a single stock to include a complex set of concerns [2,3] from a wider range of stakeholders [4]. With the expansion of objectives for fisheries management to include ecological and socio-economic values, the list of trade-offs has been expanded to include impacts on both society and the environment in the present and, through the concept of sustainability, into the future. The risks most widely considered include the probability of the spawning stock biomass and fishing mortality falling outside of the desired range defined by target and limit reference points. However,

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impacts on non-target species, habitats and fishing income, catch levels and catch variability, along with their associated uncertainties, have also become objectives in scientific assessments [5,6]. While the use of Management Strategy Evaluation [7] requires identification of multiple management objectives [8], visualisation helps to facilitate and structure discussions between scientists and stakeholders [9].

Fisheries are at the interface between science and policy, and with the involvement of multiple stakeholders [10], governance cannot be successful without effective communication. Different stakeholders hold different values with respect to environmental, economic and social goals and it is vital that information about trade-offs is conveyed in a manner that is consistent with a plurality of values and without creating prejudices that might influence decisions. Relating complex scientific information, such as model outcomes, to stakeholders is fraught with difficulties but fisheries can learn from the more general experiences of graphic designers within the field of information visualisation [11–16].

It is important that the design of visualisations is informed by the science on perception of images and tailors these lessons to the specific properties of the data and their intended use [17,18]. The examples of visualisations in fisheries used here reference well-established sources of design theory and the perception of graphical information.

Information design and data visualisation are being developed in many fields to portray not just knowledge but also the uncertainty (and its causes) [18–23]. For example, doctors need to present information about the trade-offs between different risks to patients (e.g. treatment versus no treatment), while meteorologists need to communicate the uncertainty of weather predictions to the public, and climate scientists need to find ways to present complex and uncertain findings to governments, industry and the public [1,24–26]. Specific applications of visualisation in fisheries developed for MYFISH were adapted through consulting a variety of designs from these areas.

In a sub-section of this paper two fisheries related examples are presented which directly influenced the designs developed in MYFISH project. The main task for the designers was to develop a format for displaying the results of modelling in the form of Decision Support Tables (DST). Given the paucity of examples of designer-scientist collaborations within fisheries science, priority has to be given to design experience gained in other fields. Within MYFISH, scientists have collaborated with design professionals to create visualisations of multi-dimensional impacts of management options. These designs have been tested with stakeholder groups and subsequently improved. Using a Western Mediterranean case study, the following sections discuss how different design options can impact the decision making process based on the same modelling results, and conclude with lessons learned from adopting a visualisation approach to communicate with stakeholders.

Finally, an approach to convey (visually) a sense of how reliable these modelling results are is presented. Given a variety of models it is important to enable stakeholders and decision-makers to develop an independent judgment about a model's suitability and plausibility. The difficulty is to condense information about the quality of the data, the relative depth of knowledge, the robustness of the model and the extent to which the model has been validated into a single graphic that can help contextualise modelling results. The model reliability visualisation is based on detailed standardised questionnaires posed to ten modellers working on different case studies. The variety of fishery contexts and models that were included in the questionnaire demonstrate transferability of this methodology. It is a generic way to compare very different models to each other qualitatively. The information about reliability of the model is rarely synthesised systematically or communicated to decision-makers, albeit previous EU projects have begun to tackle this issue. The four point scoring system for the data and knowledge quality is adapted from an EU FP7 project JAKFISH which searched for a common presentation format in which models can be compared.

In this paper, approaches to communicating modelling results and their reliability are presented as starting points for developing a visual language for fisheries science that takes advantage of advances in information design technology and software.

2. Methodology

2.1. Previous applications of design in fisheries

Research on visual perception followed closely on the developments in information design pioneered at the beginning of the 20th Century in Vienna [27]. The greatest contribution to the development of modern visual language came from a Viennese school of designers, in particular Otto and Marie Neurath, who pioneered ISOTYPE – the International System of Typographic Picture Education [27].

The ISOTYPE (icon array) visualisation techniques are still commonly used in information design [28]. Icon arrays have been demonstrated to be extremely effective visual tools when used to compare quantities in the same units [20]. There are few examples of icon array use in fisheries, especially in the academic literature. The majority of examples found were produced by non-governmental organisations (NGOs).

The Pew Trust has used Fig. 1 to depict the impact of growth overfishing. This illustration breaks several rules of what might be considered 'best practice' for fisheries in order to make a point. For example, the size of the fish, which is meant to represent the relative change in the average length, is not drawn to scale. The length of the "Today" fish is half that of the '1962' specimen according to the numbers given (33 in. vs. 16 in.) but this information is pictorially distorted, possibly for greater emphasis. Our perception of change might be subconsciously based on area rather than length of the fish depicted, and therefore the 'Today' fish which has been drawn 11% smaller in length than it should have been could translate into a bias of approximately 21% in terms of the area of the depicted fish.

Another problem with this representation (Fig. 1) is the use of the same icon to refer to both eggs and spawners, thereby creating visual conflation. It is better to be consistent in the use of icons so that audiences only need to learn the design language once [26]. Specifically, each icon should only represent a single meaning. In developing design approaches within MYFISH, the kind of ambiguity found in Fig. 1 was avoided. The same example also raised awareness of how the size icons may affect perceptions of the information. It is good practice to avoid such conflicts in the depictions of relative differences in values.

In addition to finding an example of using icon arrays within fisheries to inform about change over time (Fig. 1), a fisheries example was found that compares two kinds of fleet based on several criteria using a similar visualisation technique (Fig. 2). This visualisation, developed by Archipelagos Institute of Marine Conservation, served as

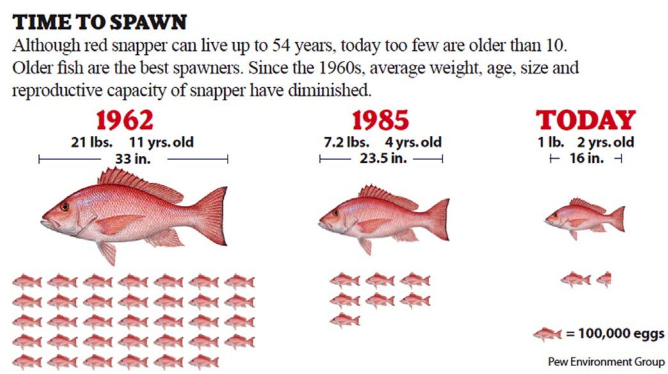

Fig. 1. Time to Spawn. Pew Environment Group uses icon arrays to show how fertility has declined with the average size of the fish in a red snapper fishery. © 2011 The Pew Charitable Trusts.