Does Operational Oceanography Address the Needs of Fisheries and Applied Environmental Scientists?

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ABSTRACT. Although many oceanographic data products are now considered operational, continued dialogue between data producers and their user communities is still needed. The fisheries and environmental science communities have often been criticized for their lack of multidisciplinarity, and it is not clear whether recent developments in operational oceanographic products are addressing these needs. The International Council for the Exploration of the Sea (ICES) Working Group on Operational Oceanographic products for Fisheries and Environment (WGOOFE) identified a potential mismatch between user requirements and the perception of requirements by the providers. Through a questionnaire (98 respondents), WGOOFE identified some of these issues. Although products of physical variables were in higher demand, several biological parameters scored in the top 10 rankings. Users placed specific focus on historic time series products with monthly or annual resolution and updating on similar time scales. A significant percentage requested access to numerical data rather than graphical output. While the outcomes of this survey challenge our views of operational oceanography, several initiatives are already attempting to close the gap between user requirements and products available.

INTRODUCTION

Operational oceanography aims to provide oceanographic information and data in a routine manner from observations and/or models for regular use (Nowlin and Malone, 2003). The Global Ocean Data Assimilation Experiment (GODAE; Bell et al., 2009) pioneered the use of real-time global forecasting, and over the past decade, a significant amount of effort has been devoted to the development of pan-European operational capability through European projects such as the Marine Environment and Security for the European Area (MERSEA; http://www.mersea.eu.org) and the European Coastal Sea Operational and Observing and Forecasting System (ECOOP; http://www.ecoop.eu). As a result, many oceanographic data products are now considered operational, and the concept has become a reality. Advances in modeling biogeochemical systems, together with increased computer power and societal demand for this information, have translated into the expansion of operational systems to include fully coupled ecosystem models and their products (Brasseur et al., 2009). Many of the current suite of operational products are oriented toward real-time monitoring and short-term forecasting (e.g., ECOOP and MyOcean, http://www.myocean.eu.org). It has always been clear, however, that the products made available must be developed in collaboration with their users (Nowlin and Malone, 2003; Polfeldt, 2006).

One of the perceived user groups of operational oceanographic products is the fisheries and environmental scientific community. This community is often criticized for failing to be multidisciplinary in focus (Olsen, 1988; Kjell, 2003; Pontecorvo, 2003), and when it is, it is under pressure to offer integrated ecosystem advice and assessments (Sissenwine and Murawski, 2004). Have the recent developments in operational oceanographic products addressed the needs of this community, and are the producers really talking to the users?

The International Council for the Exploration of the Sea (ICES) is an umbrella organization for marine scientists working in the North Atlantic. Apart from its role in stimulating and enabling science, it also offers operational fisheries advice and is moving toward providing ecosystem advice. It also provides a focus for oceanographers in Europe and North America. The Working Group on Operational Oceanographic products for Fisheries and Environment (WGOOFE) was established to encourage communication among fisheries, environmental, and oceanographic researchers and to ensure that the needs of potential users of oceanographic products were being heard. Addressing the lack of communication among marine scientists working in various disciplines is viewed as a core step toward achieving an "ecosystem approach." This lack of communication has been cited as one of the origins of the possible failure of fisheries management (Pontecorvo, 2003).

Through the work of WGOOFE, it became apparent that a mismatch existed between user (environmental and fisheries scientists) requirements and the perceived requirements identified by the producers of oceanographic data products (ICES, 2009). To gain more information, a questionnaire was launched across the ICES science and advisory community to investigate oceanographic data requirements. These results now need to be widely and openly communicated to the producers of operational products, especially as the survey highlighted differences between the average ICES user's needs and current provision. This survey is timely as several new initiatives aimed at improving dissemination of oceanographic products to the user community are beginning. There is also a drive across the applied marine science world to produce integrated ecosystem assessments. We feel that while the questionnaire may not be representative of the marine science community as a whole, it does provide a strong reflection of the needs of fisheries and environmental scientists.

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THE QUESTIONNAIRE

A questionnaire (http://www.wgoofe.org/objectives) was circulated to members of the ICES community involved in research and advice in fisheries and the marine environment. The majority of the questionnaires were completed in the presence of a member of WGOOFE, allowing questions about interpretation to be addressed. The questionnaire was split into three main topics:

1. Respondents' research backgrounds (their subject areas, roles and expertise, data handling skills, and software knowledge)
2. Data products they require (variables, resolution, spatial and temporal horizons)—respondents were asked to choose their required oceanographic variables from a predetermined product list
3. Preferred data-delivery mechanism (ease of access, time scales, and formats)

For most of the questions, respondents could check more than one answer. The majority of questionnaires were completed during meetings devoted to discussing data requirements. Respondents remained anonymous. The data were collated and the survey results (by category) tested against the likelihood of respondents choosing categories in a random manner using a chi-squared test with William's correction (Sokal and Rohlf, 1995).

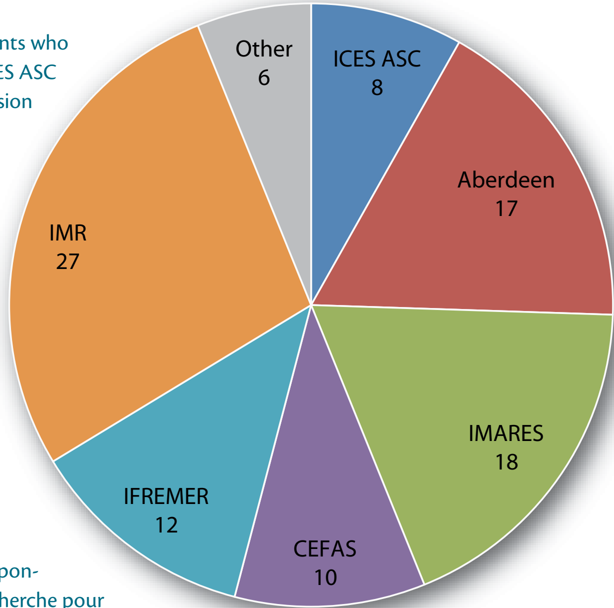

Figure 1. Affiliation of respondents who answered the questionnaire. ICES ASC = answered during a special session at the International Council for the Exploration of the Sea Annual Science Conference, Berlin. Aberdeen = answered during a special session at Marine Scotland Science, UK. IMARES = answered during a special session at Institute for Marine Resources and Ecosystem Studies, The Netherlands. CEFAS = answered via correspondence at Centre for Environment, Fisheries & Aquaculture Science, UK. IFREMER = answered via correspondence at Institut français de recherche pour l'exploitation de la mer, France. IMR = answered via correspondence at Institute for Marine Research, Norway. Other = answered by correspondence by other researchers, not affiliated with any of the previous groups.

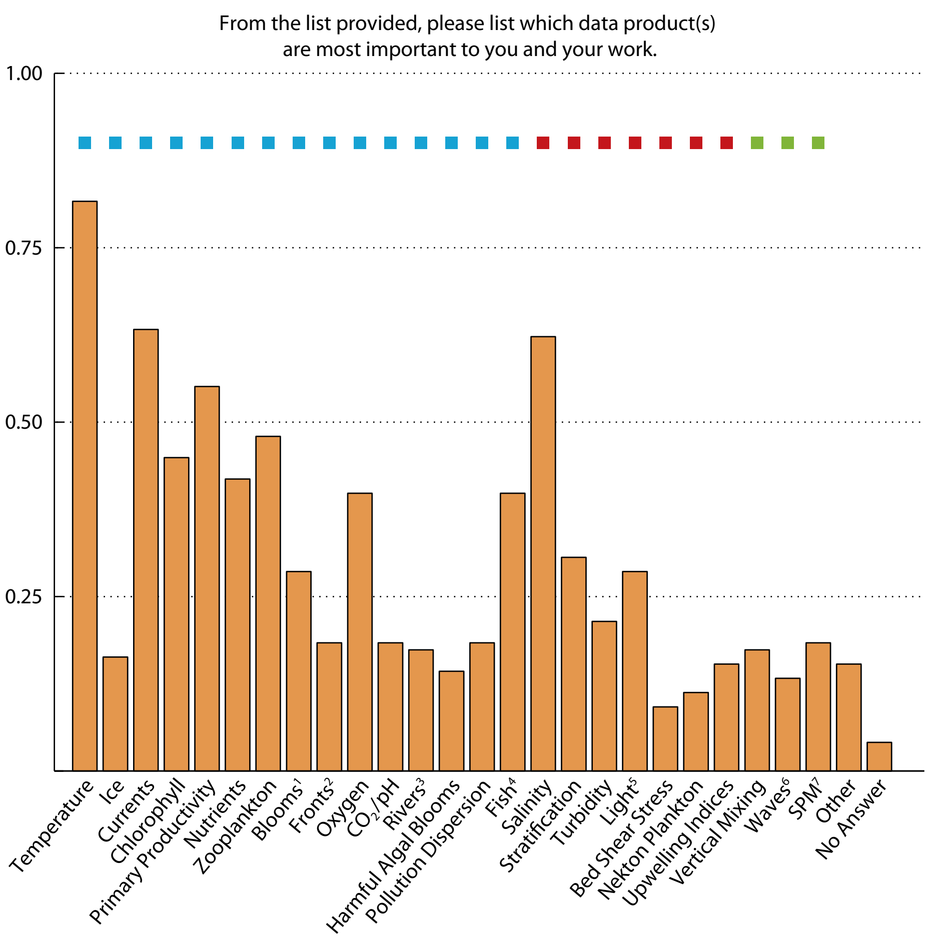

Figure 2. Required oceanographic variables for data products. Variables in the horizontal axis sorted according to initial ranking (ICES, 2009) with squares representing original ranking: blue = high, red = medium, and green = low. [1] Blooms = bloom time/duration/intensity. [2] Fronts = location of frontal regions. [3] Rivers = river plumes and loads. [4] Fish = fish larvae growth and distribution. [5] Light = light in the water column. [6] Waves = wave height and direction. [7] SPM = suspended particulate matter.

RESULTS

In total, 98 scientists responded from a range of institutes that broadly reflect the scope of ICES (Figure 1). Approximately 75% of the respondents classed themselves as "intermediate" or "expert" in data handling, and over 50% of the respondents said that they handle data sets at the megabyte size or less, which is considered small in terms of operational oceanography.

The variables listed in the questionnaire (e.g., temperature, CO_2) had been previously classified as high-, medium-, or low-priority products (Figure 2) by WGOOFE (ICES, 2009). These classifications were generally similar to those of the respondents (Figure 2). Data products on temperature, currents, salinity, chlorophyll standing stock, and primary production were most requested. Salinity was requested more than expected from the prior classification, and ice coverage and timing much less than expected. Products providing physical variables were in higher demand than those related to biology or chemistry, although products providing zooplankton production and standing stock, oxygen, and planktonic fish distributions were in the top 10 rankings.

All survey questions on data format and delivery were significantly different from a random pattern (Figure 3), suggesting that the survey results were indicative of respondents' preferences. The respondents wanted data products with monthly or annual resolution (aggregated to this temporal scale) of a historic time series. The preference was for annual, quarterly, or monthly updates to these series (Figure 3). Respondents were more ambiguous about vertical resolution, with surface/bottom and vertical bins both scoring similarly. The majority also requested broad-spatial-scale aggregations of data from 10 km to larger (sea or region). Good-quality metadata on the methods used was also seen as important (at 60%). Many operational oceanographic products currently offer only graphical outputs such as maps, and this result contrasted greatly with the requirements of the respondents; 91% wanted to be able to download the numerical data.

Although NetCDF files are becoming standard for the delivery and manipulation of meteorological and oceanographic data, the majority of users requested delivery in ASCII or spreadsheet formats. This preference was similar across scientists, regardless of their data manipulation and software expertise.

DISCUSSION

The group of respondents was a relatively small proportion (6%) of the whole ICES community of 1800 active scientists, and the questionnaire was only circulated at certain target institutes. Nevertheless, the coverage in terms of geography, discipline, and institute type is thought to be representative of the ICES community (Figure 1). Similarities in the answers of the respondents also added weight to the impression that the user group had been correctly targeted. We are aware that many operational oceanographic initiatives request feedback from their users; however, there is little evidence that those results are published as internal reports or citable literature. Thus, the aim of this work is to publicize to the wider operational oceanographic community the requirements of fisheries and environmental scientists.

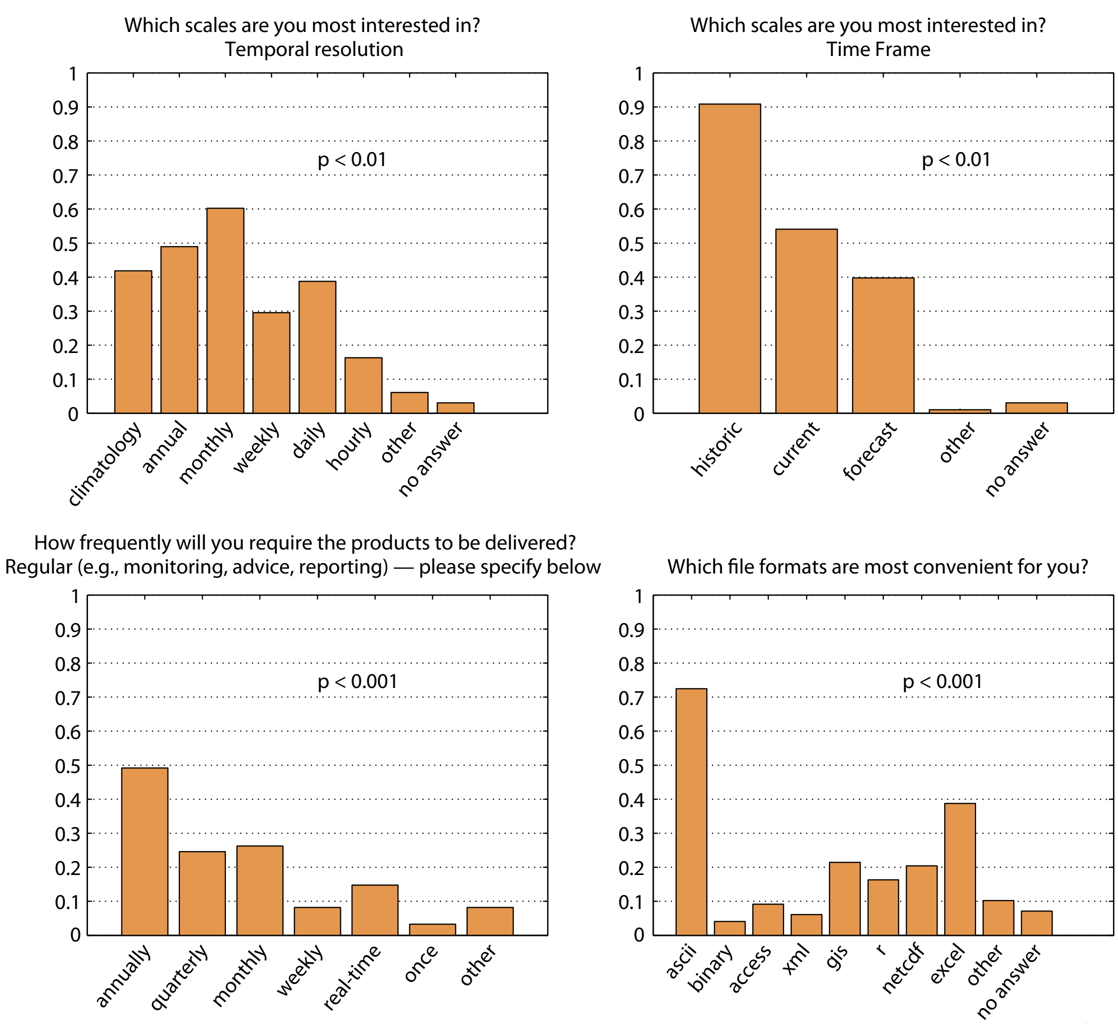

Figure 3. Data products required and data formats requested. Respondents could choose more than one option. The P values show the chi-squared test of the results against purely even results for all categories (other and no answer not included).

The variables required by the users were broad, as expected. Previous analysis (ICES, 2009) suggested that the users would require information on ice cover and, to a much lesser degree, salinity. This presumption appeared to be incorrect (Figure 2), as salinity was ranked third by the users and ice cover was not highlighted as that important. Many physical oceanographic products are coming online, but the ranking near the top of the list of biophysical products suggests that researchers also need integrated coupled analysis from chemical and biological oceanography. The high score for fish-related products, such as ichtyoplankton abundance and distribution, suggests that, within the fishery science user community, these data are now regarded as part of operational oceanography. In the future, developing such products and including them in the product catalogue will require close collaboration between environmental and fishery oceanography researchers.

Results of the survey challenge the current restricted focus of operational oceanography on real-time ocean observing and continuous forecasting. We interpret "operational" as being service oriented, delivered on demand, and generic (Nowlin and Malone, 2003). These characteristics are being met by real-time observatories and forecast products. However, researchers in fisheries and environmental science indicate that they need high-quality time series (historic data) that are regularly updated and flexible in terms of spatial and temporal limits and resolutions more than they need real-time and short-term forecasts. Recently, long time-series of products have become publicly available through MyOcean from hindcast and reanalyses (Bahurel et al., 2009), a move toward remedying this disconnect. Users also requested forecasts that are either seasonal or multiannual, something that science still cannot reliably provide, while there is little interest in five-day forecasts from this community.

Although the survey highlights user needs, it also suggests that data providers must consider communication with, and education of, data users (Polfeldt, 2006). Target users did not seem to understand the magnitude of data available, which has implications for its use and manipulation. For example, requests for monthly average fields on a 10 x 10 km horizontal, 10-m depth bin vertical resolution for the North Sea for the past 40 years cannot be accommodated via ASCII file formats. Either users will need to familiarize themselves with scientific data formats, such as NetCDF, or providers will need to incorporate new Web applications and services to allow less-familiar users to preselect subsets of data and download them in a choice of formats (e.g., THREDDS, Live Access Servers, Dapper). In our experience, fisheries scientists have been overwhelmed when asked what data they want, so they request everything. These scientists then complained that they could not cope with the large size and awkwardness of the data when they were delivered. To improve this situation, interaction between producers and users must be continual so that products evolve to serve users' changing needs and expectations. As environmental and fishery managers integrate more data in the spatial dimension, and data delivery becomes more operational, product requests are likely to change rapidly. Challenges associated with data delivery, such as data quality, data ownership, and lack of influence on their use, are often raised as concerns (Lamb and Davidson, 2002), and these concerns can only be addressed by transparent communication.

Often, the lack of citable sources for the data products reduces the applicability of products for the research community. Attributing data to "grey" sources becomes a problem when publishing in peer-reviewed publications. Editors, reviewers, and scientists need to find a solution to this issue, and oceanographic data providers should be encouraged to publish their operational oceanographic products in the peer-reviewed literature. The rapid growth of both modeling and remote-sensing capabilities has led to the frequent production of new products at short time intervals, with older versions of a model run or algorithm often being difficult to access. The ongoing International Oceanographic Data and Information Exchange-Scientific Committee on Oceanic Research (IODE-SCOR) project on data citation could also provide a possible way to break down this barrier (Blower et al., 2009; IOC, 2008).

It appears that the producers of operational oceanographic products are investing in the development of tools to deliver data in real time and at high resolution, and have accordingly built large systems to handle these kinds of requests. However, this study shows a different requirement, where research-based users require analysis products that aggregate information both spatially and temporally. They also request historic time-series information. This serious mismatch between the expectations of the end users and the perception of data providers needs to be realigned to ensure the true operational delivery of oceanographic and environmental products.

The ramifications of these survey results for operational oceanographic data providers are difficult to gauge. Historically, in fisheries and the environmental sciences, providers were mainly government-funded institutions. More recently, though, academic researchers have provided products through collaborative research projects. The former are exemplified by the German *Bundesamts fur Seeschifffahrt und Hydrographie*, which produces freely available operational data products in response to its government's core projects and legal reporting obligations, such as the Oslo-Paris Convention (OSPAR) or EU Marine Strategy Framework Directive (MSFD). These institutes do not depend on three- to five-year project funding, and are therefore able to continue long-term observations and modeling efforts. However, rigid budget constraints permit little flexibility in user-friendly data distribution, although some, such as the UK Met Office, see specific user-targeted products as very important. Academic research institutions, such as the University of Bergen, on the other hand, provide data products that were originally created in collaborative projects. Although continuation of the data provision is less certain, these products are generally better developed for the environmental/fishery scientist, and these providers are quicker to merge new scientific information into their products. A closer working relationship between the different kinds of operational data providers could be beneficial for all involved.

Mechanisms or interfaces need to be found to address marine data users' lack of knowledge about and inexperience with the magnitude of data available and their delivery from the producers. Dialogue and education is also needed to enable users be more specific about their data requirements and needs. More communication within the producers' community could speed up this process. For any oceanographers wanting to make their data more useful and functional, the crucial first step toward scientific progress is to take the data out of the drawer and make them easily and freely available. Producers also need to develop tools that provide manageable historic time series. Combining the complexity of production with the simplicity of delivery is essential for progress.

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