Potentials and Limitations of Coastal Web Atlases

A Coastal Web Atlas (CWA) is a valuable resource for a range of users including coastal managers as it provides easy access to maps, spatial data, coastal information and tools. A trans-Atlantic workshop on "Potentials and Limitations of Coastal Web Atlases", held in Ireland in July 2006, brought together atlas developers and coastal data experts from Europe and the United States to examine state-of-the-art developments in CWAs and future needs. This paper focuses on workshop outcomes, including what defines a CWA and an overview of international, national, state and regional atlas case studies from both sides of the Atlantic. Results of discussions are presented concerning issues related to design, data, technology and institutional capacity for existing CWAs based on the collective experience of workshop participants. Directions in CWA development and applications since the workshop are also discussed. A major outcome of the workshop was the initiation of an International Coastal Atlas Network. The insights provided give a framework for CWA developers and a useful point of reference for coastal managers and policy makers on atlas potentials and limitations.

Key words *coastal atlas, spatial information, data management, web GIS, ICAN*

Introduction

Coastal mapping plays an important role in informing decision makers on issues such as national sovereignty, resource management, maritime safety and hazard assessment. Governments, industry sectors, academic institutions and non-governmental organizations have a tremendous stake in the development and management of geospatial data resources. Good access to relevant geospatial data is particularly pertinent for planning in the coastal zone where, worldwide, some of the largest cities and most densely populated rural and urban areas exist (United Nations Population Fund, 2007). Various governments have noted the importance of coastal mapping and are initiating programmes and activities to address both data and accessibility issues. The European Commission published its vision for an integrated maritime policy for the European Union (European Commission 2007), which called for the establishment of an appropriate marine data and information infrastructure as well as development of an Atlas of the European Seas for use in awareness raising and regional ocean governance and management. On the other side of the Atlantic, the reports of the Pew Oceans Commission and the US Commission on Ocean Policy (Pew Oceans Commission 2003; Juda 2005) clearly show that geographic technologies are a fundamental tool to address the threats of climate change, coastal hazards, overpopulation, and more.

Diverse data of relevance to the coastal zone are held by a broad range of organisations and can often be difficult to access (Millard and Sayers 2000). Efforts to improve data accessibility are often driven by legislation on a variety of topics such as environmental management, open access of public sector information, data standards and data harmonisation. Legislation, such as the US Coastal Zone Management Act (US Congress 2000) and the European Union (EU) Water Framework Directive (European Parliament 2000), require better access to data in order to improve environmental management. Legislation on open access of public sector information, such as the US Freedom of Information Act (US Congress 2002) and the EU Public Sector Information Directive (European Commission 2003), require that government agencies make their data available to those who request them. Legislation that provides for data standards and encourages data harmonisation, such as the US National Spatial Data Infrastructure (Clinton 1994) and the Infrastructure for Spatial Information in the European Community (INSPIRE) Directive (European Parliament 2007), provide a valuable infrastructure that makes data sharing technically easier.

In this context the trans-Atlantic workshop on "Potentials and Limitations of Coastal Web Atlases", held in Ireland in July 2006, which brought together key experts from Europe and the United States to examine state-of-the-art developments in CWAs and future needs was very timely. This paper presents the results of discussions concerning issues related to design, data, technology and institutional capacity for coastal web atlases based on the collective experience of workshop participants. It also provides some more recent examples of how CWAs are being used by professionals in spatial planning and as educational tools for both students and the wider public.

Coastal Web Atlases

The Internet is a valuable tool for providing access to geospatial data, for a range of users including professionals and the general public. The development of Geographic Information System (GIS) based web mapping products has improved the usability of GIS by non-specialists. This, combined with the needs of the coastal and marine community, has resulted in the growth of a niche group of interactive coastal web atlases (CWAs) around the world. CWAs cover an array of scales, ranging from the estuary level (Virginia Institute of Marine Science 2011) to entire national coastlines (University College Cork and University of Ulster, Coleraine 2011; Maritime and Coastguard Agency et al. 2011; Co-ordination Centre for Integrated Coastal Zone Management in Belgium 2011). The 2006 Green Paper on Future Maritime Policy in the European Union stated: "a veritable Atlas of EU coastal water could serve as an instrument for spatial planning" (European Commission 2006, p. 35), illustrating the increasing recognition of the potential of CWAs, even at an international level. As an outcome of policy discussions, the European Commission launched a prototype European Atlas of the Seas in 2009 to serve as an educational tool on European coastal issues and maritime heritage (European Commission 2011).

A coastal web atlas can be defined as: *a collection of digital maps and datasets with supplementary tables, illustrations and information that systematically illustrate the coast, oftentimes with cartographic and decision-support tools, and all of which are accessible via the Internet.* CWAs deal with a variety of thematic priorities (e.g., oil spills or recreational uses) and can be tailored to address the needs of a particular user group (e.g., coastal managers or education). There are many functions which a CWA can provide. Given its ease of accessibility it is a resource which can appeal to a broad audience, thus serving as an educational tool which raises people's consciousness about coastal topics (O'Dea et al. 2007). An atlas can serve as a portal that improves efficiency in finding coastal data and information from diverse sources. It can provide a comprehensive and searchable data catalogue for up to date geospatial data which is frequently changing. These were some of the driving forces behind the decision of the Ocean Data and Information Network for Africa (ODINAFRICA) to develop the African Marine Atlas (AMA), which has brought together data for 25 coastal African States (Scott and Reed 2010). A similar rationale is behind the development of the Caribbean Marine Atlas (CMA) (International Oceanographic Data and Information Exchange 2011).

CWAs can also provide much of the baseline information, interactive tools and resources for Maritime Spatial Planning (MSP) and empower users to participate in decision making and find their own answers. For example in the United States, the West Coast Governors' Agreement on Ocean Health (State of California et al. 2010) includes in its action plan the need for harmonized ocean and coastal maps and information that also cross administrative boundaries. This is supporting efforts by coastal atlas developers in Washington, Oregon and California as part of the West Coast Regional Ocean Partnership's response to the new US National Ocean Policy. As part of the European Union's actions on MSP, the need for detailed data covering a range of thematic areas in the coastal area is noted (European Commission 2010). Moreover the need to collect this data across maritime regions and from a wide range of stakeholders is highlighted. Individual coastal atlases can address this need, but it is vital that they be compatible and interoperable with each other (Meiner 2010).

An example of an atlas which provides interactive tools in relation to MSP is the California Ocean Uses Atlas (http://www.mpa.gov). This provides data on 27 different uses of the sea and has built a use density map, which can be overlaid with proposed Marine Protected Areas. Such an atlas allows users to appreciate the issues surrounding marine use and designation and can aid understanding in regard to resolving different stakeholder planning requirements. More elaborate tools, which provide decision support within a participatory framework such as MarineMap (http://www.marinemap.org) have also been built using many features that are found in CWAs.

CWAs also have a role to play in the development of Spatial Data Infrastructures (SDI) as they provide many of the required relevant data sets, mapping tools and contextual information. These can be at different scales. In Ireland, the Marine Irish Digital Atlas (MIDA) is a node within the Irish Spatial Data Exchange which is a prototype for the development of a national SDI (Marine Institute et al. 2011). At the European level INSPIRE is driving the development of harmonised national SDIs and coastal atlases are aligning themselves with its requirements in terms of metadata standards (e.g. ISO 19115, 19139), data view, download and other services (Maelfait and Belpaeme 2009). In the U.S. there are moves towards a national coastal SDI which would potentially see the development of a "Federated Coastal Atlas of the US" (LaVoi et al. 2010).

Trans-Atlantic Cooperation

While significant capacity has been built in the field of web-based coastal mapping and informatics in the last decade, little has been done to take stock of the implications of these efforts or to identify best practice in terms of taking lessons learned into consideration. In order to address these issues, funding was obtained through the U.S. National Science Foundation (NSF) and the Marine Research, Technology Development and Innovation (RTDI) Programme in Ireland, to organize two trans-Atlantic workshops on coastal mapping and informatics. These workshops provided an opportunity to bring together key experts from Europe and North America to examine state-of-the-art developments in web-based coastal mapping and informatics, future needs in mapping and informatics for the coastal practitioner community and potential opportunities for collaboration.

The first workshop, entitled "*Potentials and Limitations of Coastal Web Atlases*," was hosted by the Coastal and Marine Resources Centre (CMRC) at University College Cork in Ireland from July 24th to 28th, 2006. This workshop brought together over 40 participants from academia, government agencies and conservation organizations from Europe and North America to share technological knowledge and lessons learned from the development of national, state and regional CWAs. A variety of aspects were examined, including institutional capacity, technology, atlas design and data issues. Among the key aims of this workshop were the identification of state-of-the-art approaches to marine and coastal mapping and informatics and lessons learned from participants' combined experiences, as well as the development of guidelines as a resource for developers and decision makers on CWA projects. The workshop also aimed to create and strengthen relationships between experts in the field of marine and coastal mapping in North America and Europe, including making recommendations on the development of a joint programme of work to relevant funding bodies, as well as the planning of the follow-up workshop, entitled *"Building a Common Approach to Managing and Disseminating Coastal Data, Maps and Information,"* held at Oregon State University in July 2007.

This article summarises the findings from the Coastal Web Atlases Workshop, presents some relevant developments since, and provides recommendations for those wishing to develop CWAs of their own (O'Dea et al. 2007). It also aims to highlight significant issues which need to be addressed, both within the coastal mapping community as well as by those with a stake in the management of data relevant to the coastal zone.

Coastal Web Atlas Development

The process of designing and developing a CWA involves many challenges. A CWA should be an effective resource for delivering coastal information and geospatial data to its target audience, packaged in an intuitive web interface which uses reliable state-of-the-art technology. It can also be designed to be a practical tool for coastal managers.

Characteristic Coastal Web Atlas Features

Based on the definition of a coastal web atlas previously given, an atlas contains a collection of maps with supplementary tables, illustrations and information which systematically illustrate the coast. Access to the various components can be provided in different ways. The typical CWA contains a number of general features which are common to most if not all of the case studies (Fig. 1).

< Insert Figure 1 here >

Fig. 1 This image of the interactive map page of the Marine Irish Digital Atlas (http://mida.ucc.ie) illustrates one example of providing access in a single web page to various CWA components

Map Area

The map area displays geospatial data as either static map images or interactive maps where users can zoom in to areas of interest and query particular map features for more information. It may also contain a small overview map of the entire geographic area, a scale bar, geographic coordinates, an atlas watermark and copyright information.

Geospatial Data

The maps displayed are composed of geospatial datasets (e.g., point, line and area features, raster grids and/or images) from one or many data owners. The user generally has control of the data displayed to varying degrees, such as viewing selected individual layers or data grouped by theme (e.g., protected areas, marine biology). The number of datasets viewed at one time can be infinite or limited by the developer, and may be displayed in the map area as images or vectors, depending on the web mapping system functionality. Data will sometimes be limited to viewing at a particular range of scales to avoid misrepresentation of data, such as displaying data created at 1:1,000,000 when a user is looking at a small estuary at 1:10.000. Data can sometimes be downloaded from the atlas, depending on licence agreements with data owners.

Legend/Layer List

A legend defines the symbols and colours used to display map features. Alternatively, the layer list is generally provided to give the user control of the layers which are viewed in the map, sometimes giving users the ability to turn layers on and off in the map area. The legend and layer list can be displayed separately or combined together. They can appear in the same window next to the map or open in a separate pop-up window. CWA developers can design the legend and layer list to be a static, predetermined list or a dynamic, user-modified list. For example, the user can control the layers that appear in the list, either by selecting individual data layers from a master list or by selecting a theme of grouped layers.

Atlas Tools

There are many tools which can be included in a CWA, depending on the atlas purpose. An atlas can simply allow a user to zoom to an area of interest or identify map features and see related attributes. An atlas can provide tools which enable users to search for specific datasets relevant to their interests (e.g., title, keyword, date, area). Further functionality can enable the user to perform more advanced queries for features within a dataset itself (e.g., site name, value or range of values) or offer tools to perform spatial analysis using data within the atlas and visualise the results in the map. Tools can be designed to address specific needs of certain user groups. These tools can be embedded in the map interface or presented as individual web pages that target a specific audience or task.

Attribute Tables

The information held in the attribute tables of geospatial data can be made available to atlas users. These tables provide additional information about map features to the user, including fields such as names, types and quantities. Attribute tables can generally be accessed by using an Identify tool and then selecting a feature in the map. Table results can appear in a separate part of the map page or in a pop-up window and are sometimes accompanied by a map highlighting the feature selected. Table results can display details for a single map feature selected or for map features in multiple layers located under the selected point or area.

Metadata

Metadata, or data about data, is a crucial component of a CWA. They provide the source information for the various geospatial layers, such as ownership, the date and scale at which data were created. Metadata inform users of the quality of the data and enable more advanced atlas users to find data layers of relevance to their own work. Metadata available in atlases can be displayed in a standardised format or as the data owners provide them, and can consist simply of basic metadata information or offer full details about the datasets. Varying levels of metadata may be available, presented in a tiered system which provides various levels of detail. They can be displayed as simple web pages or stored in a database and dynamically presented in a template. Metadata records can also be exportable in a format that enables sharing with other metadata databases and search engines.

Information/Extras

Additional relevant information adds value to the map display by helping to highlight specific coastal topics (Fig. 2). Information can include general and detailed descriptions of topics and issues relevant to the atlas purpose and can provide resources for specific user groups (e.g., coastal management, education, tourism). These information and resources can include photos, documents and links to relevant web sites, organisations and external documents.

<Insert Figure 2 here>

Fig. 2 The Oregon Coastal Atlas contains a Learn section, which educates users about topics such as habitats, coastal erosion and beach water quality (image: courtesy Oregon Coastal Atlas)

Behind the Scenes

Powerful server and software technology are used to support the hosting of a CWA. Atlas design takes into account available financial and technical resources, audience needs and limitations, system architecture, web design and content management. Atlases can be hosted on one of several operating systems (e.g., Microsoft, UNIX/LINUX) and be based on a variety of web servers (e.g., Microsoft IIS, Apache). Software utilised to construct web GIS and database management systems can be proprietary (e.g., ArcIMS, ArcSDE) or open source (e.g., University of Minnesota MapServer, PostgreSQL). Database management systems (DBMSs) can be employed to manage atlas web and/or data content. Alternatively the web GIS and atlas content can be designed with direct access to files, including geospatial data. Atlas design can take into consideration the best available technology for the atlas purpose, along with the network speeds of users. Atlases may meet one or many national or international data and technology standards (e.g., International Organization for Standardization (ISO) 19115/19139 metadata standards, Open Geospatial Consortium (OGC) web mapping standards, World Wide Web Consortium (W3C) standards). These standards can aid in implementing data and metadata sharing across distributed networks.

Comparison of Coastal Web Atlas Case Studies

As part of the workshop, a number of representative coastal web atlas case studies from both sides of the Atlantic were presented by developers. Those included as case studies were:

- The UK Coastal and Marine Resource Atlas (CAMRA): http://.magic.defra.gov.uk (Maritime and Coastguard Agency et al. 2011);
- De Kustatlas Online, Belgium (DKO): http://www.kustatlas.be (Co-ordination Centre for Integrated Coastal Zone Management in Belgium 2011);

- The Marine Irish Digital Atlas (MIDA): http://mida.ucc.ie/ (University College Cork and University of Ulster, Coleraine 2011);
- The Oregon Coastal Atlas (OCA): http://www.coastalatlas.net (Oregon Ocean-Coastal Management Program 2011);
- North Coast Explorer, Oregon (NCE): http://oregonexplorer.info/northcoast/ (Institute for Natural Resources and Oregon State University Libraries 2011);
- Mapping Tools for Coastal Management, Virginia (VIMS): http://ccrm.vims.edu (Virginia Institute of Marine Science 2011).

The CWA case studies which were presented provided insight into the variety of approaches taken to communicate common themes and address the needs of similar audiences at national, state and regional levels. They highlighted similarities, including common features such as an interactive map, tools and access to geospatial data, as well as unique features and common challenges encountered with atlas development and maintenance. Development and management aspects of each CWA case study were examined in the workshop's final report (O'Dea et al. 2007). These included issues involving atlas design, functionality, technology, data and management. The case studies themselves are described further in DEFRA (2006), Belpaeme and Maelfait (2010), Dwyer et al. (2010), Haddad et al. (2006, 2010), Institute for Natural Resources (2005), and. Berman and McCall (2010).

Atlas Purpose and Target Audience

Atlases were created for a variety of purposes. Some target specific coastal community needs, such as the CAMRA, which was created to provide a flexible resource for national oil spill planning in order to facilitate seamless multi-agency operational response. The NCE facilitates access to data and information on natural resource management of coastal watersheds, with a particular focus on native fish species and their habitats (Fig. 3). Other atlases cover a broad range of coastal topics and appeal to a diverse audience. For example, the MIDA was designed to provide maps, data and information on a variety of coastal themes to the general public, while also assisting professionals in identifying sources of data, information and expertise on the coastal and marine environment. The OCA has found that, while designed for coastal managers and decision makers, an indirect benefit of the atlas is its increasing use by non-specialists as well.

<Insert Figure 3 here>

Fig. 3 Oregon's North Coast Explorer includes such information as fish habitat restoration (image: courtesy North Coast Explorer: http://oregonexplorer.info/northcoast)

Distinguishing Features

While all of the atlases presented include common elements as described previously, many have notable distinguishing features which provide interesting examples of potential enhancements to a standard atlas. Two of the atlases were developed based on the work of existing resources. The CAMRA is built on an existing atlas, the Multi-Agency Geographic Information for the Countryside (MAGIC), which is useful for sharing data as well as technical support and development. DKO was originally published in book format (Belpaeme and Konings 2004) and a web version was later developed which maintains similar design aspects (Fig. 4). It is the only CWA case study that did not include a web GIS at the time of the workshop, although web GIS development is planned (Maelfait and Belpaeme 2009). The book and web versions of the atlas each proved to be successful.

<Insert Figure 4 here>

Fig. 4 This sample page from De Kustatlas Online, Belgium demonstrates the integrated design elements from the book publication with the interactive qualities of a web site. (image: courtesy Co-ordination Centre for Integrated Coastal Zone Management in Belgium)

Some atlases have distinguishing data integration and technical implementation. The MIDA is an all-island, international resource, which integrates data from Irish and UK organizations. The OCA integrates data from a distributed network of servers, using both proprietary (ESRI ArcIMS) and open source (University of Minnesota MapServer) software. Some atlases provide specialized functionality, such as the NCE's user controlled interface, which provides several levels of functionality as well as multiple map and font sizes. The OCA provides a range of advanced interactive tools on topics such as hazard management and watershed assessment.

Unique design features can offer ideas for other atlas developers. The MIDA's main atlas page was designed, with user feedback, to provide easy access to maps, data and information in a single web page. The NCE's user controlled interface provides several levels of functionality and multiple map and font sizes. Atlases focused on particular user groups, such as the CAMRA's design for oil spill planning, can address specific user needs. VIMS has several different web GIS sites rather than one atlas, each of which is tailored to specific needs such as: the *Shoreline Manager's Assessment Kit (SMAK)*; *Oil Spill Cleanup And Response (OSCAR)*; and the *Wetlands Mitigation Targeting Tool*.

Financial/Institutional Support of Atlases

All of the atlases presented were developed with direct involvement from multiple partners, with as few as two (MIDA, NCE) and as many as 12 (CAMRA). Most often the partnerships involved universities and government bodies (national and/or local agencies). Half involved an NGO, and only one atlas (CAMRA) included a professional partner. Financial support for all atlases predominantly came from national and local government agencies, either via grants or direct funding. In most cases this support was only available for initial atlas development. Acquiring continuation funding for site maintenance and data updates is a challenge for every atlas. Regular product promotion is difficult for many of the atlases, particularly as the atlases are created by groups that are not necessarily knowledgeable in how best to advertise and promote products.

Atlas Design and Usability

The design of an atlas influences its usability. A simple yet effective design can make data and information easily available to a broad audience. If not carefully designed, a more complicated atlas, such as one created to serve as a decision support tool for coastal managers, can lead to frustrated users.

The interactive map is the focal point of most atlases, with the exception of Belgium's DKO which focuses on text and uses maps as supportive, interactive illustrations. Most atlases were specifically designed to provide clear navigation and instruction on how to use the product. For many of the atlases, designing a simple, intuitive and informative web interface which combines power and ease of use was a key design goal. Half of the CWAs (MIDA, OCA, NCE) obtained user feedback during the design and development of their products to ensure that their atlas is usable by their target audiences. Four of the six atlases provide multiple points of access to the interactive maps from different parts of their website. Two CWAs provide guided navigation to facilitate user experience. For example, the Identify Feature tool in the CAMRA opens a popup window which prompts the user to select a layer name to query and then instructs them to click on a feature in the map. The NCE provides users the opportunity to control the look of the web interface by giving options on the size of the text and the map area.

Many CWAs limit the number of data layers which can be viewed in the map area at one time, which can overcome confusion associated with too much information in the layer list/legend and on the map itself. Most atlases enable users to select both independent layers (e.g., bathing waters, lighthouses) and layers grouped by theme (e.g., planning, geology) to view. The DKO and the MIDA were the only two CWAs to combine the legend and layer list. The others display them separately, either using legend and layer tabs within the map page or opening the respective lists in a popup window.

All but one case study (VIMS) provides thematic text to contextualize atlas content. The NCE was designed to focus on both text and map content to meet different audience needs. As an example of thematic text, the NCE presents case studies of fish habitat restoration projects along the coast. Alternatively, the MIDA InfoPort contains pages about broader topics, such as marine mammals in Irish waters. Four of the CWAs include illustrations, images and charts to further illustrate their content. The DKO, for example, displays charts and graphs related to fisheries activities. Each of the atlases found it challenging to find a balance of science and information content in order to be both informative and understandable to the target audiences. In addition to thematic pages, all CWAs but the DKO provide supplemental help pages and tutorials to demonstrate how to use the atlas. The OCA and NCE also provide a glossary to define key terms.

Another form of documentation in atlases is the metadata. All but one atlas (DKO) provide metadata for the data displayed. All of them present metadata which meet a national or international standard (e.g., the U.S. Federal Geographic Data Committee (FGDC), ISO). Four of those store their metadata in a database (e.g., Postgres). Two of the CWAs provide their metadata in multiple formats, such as the MIDA, which provides tiered Abstract, Discovery and Full Metadata to make it more comprehensible to a broader audience.

Technology Used

An effective CWA requires carefully selected technology which provides appropriate functionality, from specific web mapping tools to powerful servers and network speeds to handle site traffic. Half of the CWAs use proprietary software, the popular ESRI ArcIMS, as their web GIS. Two atlases, the MIDA and the OCA, use the open source software, University of Minnesota MapServer. DKO uses Flash instead of a web mapping system for its interactive maps. In terms of data storage, all atlases store all or some of their data on the local server. Half of those servers store the data in a database (e.g., SQL server with ArcSDE), while the other half store the data as flat files. Additionally, the OCA integrates geospatial data from a network of three distributed servers which use both proprietary and open source software. Also, the CAMRA accesses the U.K. Department for Environment, Food and Rural Affairs (DEFRA)'s Shared Spatial Information Services (SPIRE) database through a distributed network. In terms of managing non-geospatial atlas content, half of the CWAs utilise a database management system (e.g., MIDA uses PostgreSQL, NCE uses ASP.net).

None of the atlases were yet OGC compliant at the time of the workshop, although some have plans to become OGC compliant in order to improve data and metadata sharing in a distributed network. The NCE uses the Open Archives Initiative Protocol for metadata harvesting.

Available Functionality

The CWA case studies offer users a range of map functionality. Most provide a single level of capabilities, either offering standard tools (e.g., zoom, recentre, full map extent and identify features) or a broader suite of tools (e.g., query specific features in a layer, measure features and make map notations). The OCA and NCE each provide multiple levels of functionality for users to choose from, such as the NCE providing access at both standard and advanced user levels. Moderate functionality, such as layer list control and viewing data grouped by theme, are available in many CWAs. Downloadable geospatial data is available in all CWA case studies. All atlases, except the MIDA, give users the ability to print or export their maps. Only two atlases provide advanced mapping functionality, such as access to advanced geospatial tools in the NCE and the ability to query attributes within layers in the CAMRA (Fig. 5).

<Insert Figure 5 here>

Fig. 5 The CAMRA (www.magic.gov.uk) allows users to search for specific feature attributes within a designated dataset

The OCA has additional tools, separate to the main map, which enable users to answer questions related to the coastal zone, such as locating coastal access points which have specific facilities (Fig. 6) or visualising areas of potential coastal storm flooding. Four of the atlases enable users to search for geospatial data, while only two provide search functionality for other CWA content. Typical functionality is useful for a broad audience, however there is a need for more advanced functionality to provide services for coastal managers, such as improved search functionality and spatial analysis tools.

<Insert Figure 6 here>

Fig. 6 The Oregon Coastal Atlas (http://www.coastalatlas.net/) includes a resource that enables coastal visitors to find access points that meet their interests and needs (image: courtesy Oregon Coastal Atlas)

Geospatial Data Included

Overall the atlases cover a broad range of topics. Every CWA case study includes data related to Physical Environment, Coastal Habitats, Management, Infrastructure and Natural Resources. The atlases which target specific users or themes (e.g., CAMRA, NCE) have more focused and less comprehensive topics, while broader atlases (e.g., MIDA, OCA) are more all-encompassing. The least common topic is Culture and Heritage.

The numbers of geospatial data included in the CWA case studies vary greatly and can depend on the purpose of the atlas, the data resources available and how easily accessible those resources are. DKO and the NCE are relatively small with only 33/43 datasets, respectively, at the time of the workshop. The CAMRA and MIDA were more moderate, with >100/>130 datasets, respectively. The OCA had by far the greatest number, containing over 3,300 layers at the time of the workshop.

Data Issues

Intellectual property rights (IPR) and the cost of data are limitations on both sides of the Atlantic. The cost of base data in the UK and Ireland are a limiting factor in the quality and scale of data displayed, however this is not the case in Belgium or the USA where access to base data is free. The cost of some proprietary data (e.g., remotely sensed imagery, privately collected data) is prohibitive for four of the atlases. Data use restrictions are a problem across the board, with the exception of the OCA. For the MIDA, a comprehensive Memorandum of Understanding was developed to ensure appropriate use of each dataset. Written usage conditions for each layer are agreed by both data and atlas owners.

The European atlases all found data sourcing and acquisition to be significant problems, while the American atlases did not. The time which is required to source and acquire data for the MIDA can be significant, sometimes taking months of numerous emails and phone calls. Almost all CWAs (except VIMS) have issues with collating poorly managed or inaccessible data. Some CWAs found that there were limited GIS-ready data. Some atlases also faced problems concerning data duplication, such as similar datasets from different owners with slight differences.

All CWAs found that the data available is of variable and inconsistent quality. Inappropriate scales of data (e.g., 1:1,000,000 geology data for work at a local scale) are also a concern for most atlases. Most atlases encountered challenges with incomparable regional datasets between neighbouring regions, such as the MIDA's cross-border issues in developing an all-island atlas for the Republic of Ireland and Northern Ireland. In half of the CWA case studies (CAMRA, MIDA and VIMS), poor or non-existent metadata was a challenge. With the MIDA, interviews with data owners were sometimes required to collect a minimum level of metadata. The CAMRA found that there was an over-reliance on personal knowledge for data information.

The development of a data management plan for adding new data as well as providing regular data updates is a key task for nearly all atlas developers. With four of the atlases, there is a need to find a balance between atlas development and data updates. There is also a need to design tools for better atlas management. Most atlases require manual upload of data to the atlas, which requires time and resources. Adding a layer to the MIDA, for example, can take two to four hours. For half of the atlases, finding resources to continually source and acquire new data is also a concern.

Strengths, Weaknesses, Opportunities and Threats Analysis

Four issues were identified as relevant in the development of CWAs, namely atlas design, data and metadata, technology and institutional capacity. During the workshop, four working groups were established in order to explore these themes in detail by carrying out a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis (Weihrich 1982). These issues provide an overview of the situation with regards to CWA development and management at the time of the workshop and which are also of relevance today. Tables 1 to 4 provide a summary of the top five strengths, weaknesses, opportunities and threats for each theme which resulted from the discussions. Examples provided by the workshop participants are included in the following discussion.

Atlas Design

CWAs have taken advantage of the flexibility of the web to create intuitive and easy to use map pages and web sites, allowing the presentation of both data and contextual information. This flexibility can provide multiple access points to data and information, therefore permitting users to interact with the CWAs in different ways. Most of the atlases presented are strong on map visualization but offer a limited number of tools. Some, however, provide a range of interactive coastal mapping tools, such as the toolset developed by the Virginia Institute of Marine Science (VIMS). However, such diversity and flexibility can lead to use of CWAs in ways that were not envisaged by developers, leading to misunderstandings and potential user rejection. It is thus imperative that user communities are consulted throughout the design period.

This flexibility can also raise cartographic concerns related to the display of multiple data layers at the same time in a coherent and comprehensible way. There is also the risk that atlas developers are driven by their desire to use innovative technology rather than respond to real user requirements, including their need for well designed and comprehensive search functionality. For example, the emergence and popularity of global viewers (e.g., Google Earth) challenges CWA developers to consider how best to deliver data and information to user communities.

Effective data management is fundamental for CWAs as they contain large quantities of data, metadata and information. However, many existing atlases are compromised due to the lack of sophisticated database management systems although there are plans to retrofit them. Recent developments in enhanced DBMS (e.g., geoNetwork), to accompany open source web mapping technology, is facilitating this.

Distributed networks and related technologies (e.g., Catalogue Services for the Web [CSW], Web Map Services [WMS], Web Feature Services [WFS]) offer the potential for enhanced data and metadata sharing while allowing data owners more control over their holdings. For example, the MIDA is part of a distributed metadata exchange network (ISDE) with other environmental data supply agencies in Ireland (Marine Institute *et al.* 2011). Such initiatives can help overcome concerns related to restrictive data policies, high data costs and IPR issues which can impact atlas design in terms of data quality and accessibility. Networking is also facilitating the development of linked atlas communities at regional, national and international levels. For example, developers of the MIDA and the OCA have shared ideas on atlas design and technology issues and web GIS development, such as content management and web usage statistics. Also, the CAMRA is part of the UK's MAGIC atlas, which is developed and supported by a partnership of 12 national and regional agencies.

Funding limitations can compromise ongoing design enhancement of CWA. Investment is often focussed on time-limited technology demonstration projects with staff contracted for defined periods. Long term support for atlas maintenance and associated staff can be difficult to secure. For example, after the initial development phase of the MIDA funded through national research programmes, it is being maintained primarily by funds from within the CMRC.

Table 1 Atlas Design SWOT analysis results

Atlas Design
Strengths
- **Intuitive structure** of web sites and map pages;
- Inclusion of **contextual information** in order to better understand the data;
- **Hierarchical** data organisation;
- **Multiple user pathways** to retrieve maps and layers of interest;
- **Tools** for data analysis and creating reports.
Weaknesses
- The **cartography / design** challenge of displaying many layers;
- **Inadequate database management system** (DBMS) for efficient management of information, metadata and data;
- Inadequate **search functions** for data and content;
- Failure to meet user needs where atlas developments are **technology-driven**;
- **Lack of distributed systems** to enable data owners to share and manage their own data.
Opportunities
- **Open source** technology;
- **Enhanced DBMSs** to accompany open source web mapping technology to efficiently manage data, metadata and CWA content;
- Improved **cartographic display** of large quantities of layers in coastal atlases;
Potential for sharing data through **distributed networks** (e.g., utilising Web Map Services and Web Feature Services);
- Potential to develop **regional nodes** that tie in with larger atlases (e.g., national or statewide).
Threats
- **Funding** limitations (e.g., focus on technology rather than maintenance; staff turnover);
- Keeping up with **design expectations** of users (e.g., Google Earth);
- **User interpretation**: misunderstanding of how to use atlases or their components;
- **Data policies, cost and Intellectual Property Rights** issues impact atlas design in data quality and accessibility, and thus atlas functionality (e.g., spatial analysis using large scale data).

Technology

Web map publishing technology is developing rapidly, both in the proprietary and open source software domains. Support tools (e.g., XML, UML), including content management systems also aid web-mapping developments. For example, the NCE, developed at Oregon State University, is using ASP.NET technology to drive the database. They have also put a Moxi Media Internet Mapping Framework (IMF) front end on the ArcIMS web GIS. Nevertheless, technical support in the use of open source software and tools can be a concern, with less structured support than with proprietary systems. The quick evolution in technical solutions themselves can be disruptive, both for atlas developers and end users, and there is a need to balance the implementation of new technologies against maintaining stable, familiar and functioning systems.

Parallel developments in geospatial technologies can be harnessed by CWA developers to add additional functionality. Geo-tagging (e.g., geoRSS) can facilitate the incorporation of a wide range of non-specific GIS data. Recommender systems can also supplement query systems by providing additional links to information of potential user interest.

Improvements in hardware and network capacity and performance aid CWA development. Better monitor resolutions provide a more pleasant user experience whilst larger storage capacity, better processing and improving network speeds allow the delivery of ever larger datasets in a seamless manner. These improvements also support the emergence of 3D and 4D web GIS. The corollary of this is that hardware can quickly become obsolete, backup software may not support particular physical media or compatible drivers may no longer be available. Atlas developers should take potential obsolescence into account in long term atlas management planning.

Maturing standards and specifications (e.g., OGC specifications, ISO metadata and W3C standards) allow quicker development life cycles, promote code reuse and also facilitate interoperability and data sharing. Nevertheless, the lack of high quality, standards-compatible metadata, especially for historical data, can limit the utility and functionality of atlases. Atlases often pull together data from many owners and are reliant on them to provide quality metadata. For example, the MIDA developers found that many digital datasets were delivered by their owners with non-existent or poor metadata. To address this, data owners are consulted in order to provide a complete set of minimum "Discovery" metadata for each dataset displayed in the atlas (O'Dea et al. 2004). Maintaining data and metadata and keeping them up-to-date is an ongoing challenge for many development teams, but is a requirement in order to meet user expectations. With the proliferation of datasets and increases in data size and the ability to deliver them, data mining techniques can enable users to search and sort data for patterns and value added information.

Smart and appealing technological solutions can be a way to promote CWAs among policy makers and regulators and can help leverage resources for development. However the often short-term, time-limited nature of funding can curtail the on-going upgrading and maintenance of CWAs.

Table 2 Atlas Technology SWOT analysis results

Atlas Technology
Strengths
- **Improving technology** for publishing maps on the web: choice between open source (OS) and commercial-off-the-shelf (COTS) products; Maturing **standards and specifications** (e.g., OGC specifications, ISO metadata and W3C standards); Progress in **network capacity & hardware** (e.g., processor speeds, storage capacity and monitor resolutions); Contribution of **other technologies and tools** (e.g., XML, UML and content management systems) to web mapping development; Advantages of **OS tools** (e.g., broad community support, access to source code, low cost; Lack of COTS levels of technical support is possible disadvantage).
Weaknesses
- **Software support issues**: COTS software may offer more readily available commercial support, although OS software does not preclude this; - **Large datasets** can require significant disk space and are not always supported by web GIS software (e.g., raster data); - **Hardware becoming obsolete** (e.g., media obsolescence; backup software cannot deal with physical media; compatible drives no longer available); - **Inadequate metadata** may limit functionality (e.g., be incomplete, out of date and not match the data object; digital object identifiers (DOI) could be used to link data to metadata); - Web GIS is presently poor at dealing with **time series** and **3D/4D data**.
Opportunities
- **3D and 4D web GIS** riding on increased hardware and network capacity; - Simulation and **online spatial analysis**. - **Data mining**; - Widespread use of **geo-tagging** (e.g., geoRSS) to facilitate incorporation of many more items in web mapping systems; **Recommender systems** to supplement search queries; - Increased interest in CWA by policy makers and regulators as SDI initiatives become established leads to **funding potential** (e.g., EU Integrated Marine Policy).
Threats
- Difficulty in coping with **high server loading** during peak use; - **Technology evolution** can be disruptive: need to balance the exploration of new technologies against maintaining a stable and functioning system; - The challenge of **keeping data current**; - **Lack of funding** and consequent personnel turnover; - **Partners who are weak** or unwilling to co-operate.

Data and Metadata

Increased regulation in a number of areas, including environmental management, is driving the need for data collection and their subsequent dissemination. National Spatial Data Infrastructures (SDIs) in different countries set out policies and rules regarding data delivery, such as the US National Spatial Data Infrastructure and Irish Spatial Data Infrastructure (Clinton 1994; Department of Environment, Heritage and Local Government 2004). International SDIs, such as the Global Spatial Data Infrastructure, and directives, such as INSPIRE, aid and encourage the development of national SDIs (Global Spatial Data Infrastructure 2004; European Union 2007). Other government directives, such as that on the re-use of Public Sector Information (PSI) in Europe, drive requirements for governments to make certain data publicly available (European Commission 2003). This requirement for data dissemination can often reveal the spatial or temporal patchy nature of data, where there may be large areas with poor coverage. CWAs can aid the identification of such gaps and help in the specification of data collection requirements. For example, by incorporating information from a wide range of bodies, the CAMRA and MIDA have helped in highlighting data gaps and in documenting the quality of existing datasets.

Data quality within CWAs can often be difficult to determine as the original purpose and fitness for use can be hidden. The growing awareness and acceptance of internationally agreed standards governing data and metadata is helping to alleviate this among developers and users alike. Standards and specifications are maturing and gaining wide acceptance. For example, the MIDA adopted a profile of the ISO 19115 metadata standard. In Oregon, The OCA and the NCE use the FGDC metadata standard, which is the widely accepted American standard. The NCE used the Open Archives Initiative Protocol for Metadata Harvesting to acquire metadata held in other data repositories. Nevertheless much data is still inadequately documented. If CWAs manage to provide up-to-date and consistently high quality data and metadata then they have the potential to become definitive reference locations for coastal data.

CWAs help in democratising data access as they are widely accessible to a broad range of users. This can help publicise and raise the profile of data products and the organisations which create them. This can be viewed as a business opportunity in cases where commercial data are presented, however commercial organisations may need to be given incentives to encourage them to use CWAs as "shop windows". The existence of the same data on multiple portals can lead to user confusion especially if different versions are available, although distributed networks and related technologies (e.g., WMS, WFS) can help to alleviate the need to have multiple copies of the same dataset. Emerging technologies, including open source and OGC standards, are being used to enhance data sharing, presentation and online analysis. For example, the NCE has used the Open Archives Initiative Protocol for metadata harvesting from distributed systems. MIDA has used Catalogue Services for the Web (CSW) to share metadata as part of the ISDE. However, there is a need to go beyond these initial steps and share the data themselves. Technology developments are also facilitating community-building and harmonisation among atlas providers, as the introduction of controlled vocabularies and ontologies provide more powerful methods for data retrieval across multiple platforms.

The availability of CWAs can help reduce costs for organisations requiring data by reducing data search and retrieval times. However, some CWAs provide only map output, whereas more effort should be put in delivering source data and value-added products. The limited availability of built in quantitative analysis tools can also limit utility as users have to acquire the source data in order to carry out analyses themselves. Intellectual property restrictions can also restrict users' ability to work with the data.

Table 3 Atlas-Related Data and Metadata SWOT analysis results

Atlas-Related Data and Metadata
Strengths
- **Growing awareness** and acceptance of standards;
- **Regulation** is driving the need for data;
- Provides **publicity** for data products;
- **Reduced labour costs** for routine searches;
- **Widely accessible** to a broad range of users.
Weaknesses
- **Limited quantitative and analytic utility**: tools can sometimes produce suspect/alarming results;
- **Data patchiness**;
- Assessment of **data quality** is difficult on map presentations, original purpose and fitness for use can be hidden: 'pretty map syndrome';
- **Inadequate metadata**;
- Existence of **multiple portals** to same data.
Opportunities
- Focus on the delivery of **source data** and **value-added products**, not only interactive maps;
- **Identification of data gaps** and need for data collection requirements;
- **Community-building** and **harmonization** among atlas providers (e.g., ontologies);
- Become the **definitive reference** for certain data, if it contains current, good quality data;
- Use **new, emerging technologies** for data and metadata presentation/delivery.
Threats
- **New competitive technologies** for improved data access (e.g., Google Earth);
- **Intellectual property restrictions** limit data re-distribution;
- Data viewed as **source of income**;
- **Erratic funding** affects ability to develop and maintain atlas data as well as causes loss of skilled staff;
- **Lack of incentives** for data providers.

Institutional Capacity

The necessity to deliver on government policy (e.g., implement ICZM recommendations), the promotion of E-Government and the knowledge-based economy, as well as the ongoing requirement for data and information from the coastal and marine sector all help to promote the CWA agenda. In Europe the INSPIRE directive (European Union 2007) and the development of a European Integrated Maritime Policy (European Commission 2007) are driving activity in the development of tools for presenting and analysing coastal information, such as the European Marine Observation and Data Network, and the European Atlas of the Seas. In the US, the Coastal Zone Management Act (US Congress 2000) and the Executive Order to establish a National Spatial Data Infrastructure (Clinton 1994) and the more recent West Coast Governors' Agreement on Ocean Health (State of California et all. 2010) are drivers for finding innovative methods to improve coastal data accessibility. However, restrictions imposed by data licensing can limit the ability to develop innovative and value added products. For example, the MIDA and the CAMRA are restricted in their use of base data and also their ability to allow download of third party data that were created using copyright base data. In Oregon, the NCE is addressing issues of access to copyright protected materials and sensitive data. The permanent nature of government agencies can ensure institutional support for CWAs and in some cases agencies themselves have been given a mandate to develop atlases. Nonetheless changes in political drivers and priorities can expose CWAs to uncertainty.

Parallel developments of regional and national atlases provide opportunities for institutional collaboration and knowledge sharing, by taking advantage of the large amount of experience and expertise in the CWA community. This series of workshops is a practical response to this opportunity. Networking with other groups who are working to improve data and metadata quality and accessibility, such as the Marine Metadata Interoperability Project (MMI 2011), provides valuable opportunities for knowledge building and collaboration. Atlas partnering can also help in data acquisition providing opportunities to pool resources and therefore access better or more data. However, partnerships demand active participation of all partners and an openness to share knowledge and potentially data and tools.

The involvement of academic institutions as atlas hosts can sometimes reduce costs associated with data purchase and licensing, while also providing access to research and education funds. However, these funds can be project focussed and short term, which leads to difficulty with atlas maintenance. Often organisations developing CWAs have limited experience in marketing or building awareness of their products which can lead to slow uptake by users or there can be too much focus on the technology aspects with limited appreciation of user needs and expectations.

With the proliferation of online mapping applications and databases, it can be hard for CWAs to stand out. Google Earth and other global viewers challenge atlas developers to meet design expectations of users, such as speed of the system and ease of use. Most of the atlases presented use ArcIMS or University of Minnesota MapServer. DKO on the other hand, although lacking the levels of data interactivity of other atlases, has attempted to make its interactive maps "Google-friendly". Atlas credibility can be undermined if they do not contain high quality data and metadata and if they do not offer appropriate tools for decision support. For example, the CAMRA has encountered problems with inconsistent data records, poor data documentation and multiple copies of data.

Restrictions on data access due to licensing and intellectual property issues can affect developers and users alike as it can limit ability to develop innovative and value added products and the ability to pass them on freely to users. The quality of base maps in the MIDA (1:50,000 geotiffs) is limited by cost/IPR issues, therefore providing an inadequate base for certain user groups.

Table 4 Atlas-Related Institutional Capacity SWOT analysis results

Atlas-Related Institutional Capacity
Strengths
- **Academic CWA host institutions** have the ability to leverage additional research and education funds;
- **Government CWA host agencies** may have **mandate** for CWA development;
- Opportunities for **collaboration** with other institutes;
- The permanent nature of government agencies ensures long-term **institutional support**;
- Data and information requirements for the **Coastal and Marine sector** stimulate demands for CWA development.
Weaknesses
- Volatile and **short term nature of funding** and all associated impacts (e.g., staff turnover; difficult to maintain atlases);
- Vulnerability to **political trends** and changes in priorities;
- **Data access limitations**, licensing, and desire to recoup costs;
- Limited experience in **marketing** and building awareness;

-	Tendency towards **project control** limits the formation of partnerships for data sharing.
Opportunities	
-	**Collaboration**: availability expertise and experience in CWA community;
-	Movement to E-GOV and **knowledge-based economy** (e.g., geospatial data can underpin many government activities);
-	Delivering on **government policy** (e.g., implement ICZM mandate);
-	**Economic development**: open data licenses could lead to new products;
-	**Leveraging data acquisition** (e.g., opportunities to pool resources to obtain more or better datasets).
Threats	
-	Changing **policy drivers**;
-	Perception of **'too many' databases** and mapping applications;
-	Credibility is affected by **poor quality data and metadata**, poor models and decision support software;
-	Over or **poor marketing** means user expectations not met;
-	**Challenges of collaboration**: partner doesn't deliver up to specifications.

Discussion

The workshop highlighted many common issues encountered on both sides of the Atlantic with regards to CWA development and associated matters related to data accessibility, atlas design, management, technology and institutional support. A number of these overlap and influence each other. Governmental policies can drive organisations to provide institutional support for improved data accessibility and adherence to data and technology standards. Alternately both restrictive data accessibility policies and technology limitations can create barriers to CWA developers in making those data available in online web mapping services (DEFRA 2002). This can then impact atlas design and functionality. This section provides a more detailed discussion of the various issues and recommendations which emerged from the workshop, and also includes some relevant developments since.

Data Related Issues

Data cost, licensing and intellectual property considerations can limit data availability in an atlas. The high cost as well as the extensive procedures involved to use data where legal agreements are necessary can be a deterrent (DEFRA 2002). In certain countries (e.g., Ireland and United Kingdom) key base datasets reside with public bodies who must balance their commercial need for profit with their public duty to provide data in order to recover costs. In such instances, licensing costs can limit the quantity or quality of base data provided in the atlas. Cost and IPR restrictions for research and commercial data must also be negotiated, which can be time and resource intensive. In the US, government policy on Freedom of Information has been a driver for the development of data standards and data cataloguing by government agencies. The low cost and accessibility of data enables resources to be invested in research and development instead of limiting use to those who can afford the data. Longhorn and Blakemore (2004) argue that the debate on data cost and licensing has often been a dogmatic one based more on entrenched and emotional positions rather than on the arguments for and against pricing. They believe that a more nuanced approach is necessary where pricing structures are put in place based on consultations with the full range of end-users of geospatial information.

Policy makers concerned with access to geospatial data must be made aware of data needs and provide guidance on how to overcome data access obstacles. Atlas developers and data managers can play a role in informing policy makers of limitations that data cost, licensing and IPR issues impose on CWA developers. The CWA community as a whole needs to develop a collective approach on how best to address these issues.

A common concern is geospatial data quality and its inaccessibility. Methods required to address these concerns include documenting data with detailed metadata which adheres to a common standard and making that metadata available through online catalogues (DEFRA 2002). Organisations on both sides of the Atlantic are working to document and catalogue their geospatial data. Due to longstanding government policy, the US has developed a significant number of data catalogues. Policy development within the European Union is leading to improved cataloguing. Nevertheless, significant resources are required to catalogue historic data properly and to ensure the quality of newly collected data and metadata. It is vital that data owners and CWA developers use the latest data protocols to document data and enable data sharing.

Sharing of data and metadata between catalogues can be complicated by the lack of semantic interoperability. Terminology used to describe similar data and their meanings can vary between specialties or regions which can complicate data searches and data integration, for example, "seafloor" vs. "seabed" or "coastline" vs. "shoreline" (Wright 2004). A common ontology for coastal and marine data is necessary to enable exchange and integration of data. Subsequent to the workshop CWA developers have initiated coastal and marine ontology developments and prototype implementation in order to improve data discovery, sharing and integration (Lassoued et al. 2010).

Atlas Services and End-users

CWAs can be considered as "first-stop shops" as they provide an initial access point for data from a wide variety of sources. While discussing the US Geospatial One-stop Portal, Goodchild et al. (2007) argue that a "one-stop" source for GI data is virtually impossible as the number of datasets constantly increases and providers have limited resources for incorporating them in centralized or distributed catalogues and exchange systems. The same applies to CWAs. Nevertheless, users can save significant time that is often invested in searching for and acquiring data, if the atlases contain key, relevant, and up to date datasets. Moreover CWAs can provide an educational function via the data, maps and thematic content of the atlases.

A key driver for some atlases is education. The European Atlas of the Seas aims to raise awareness of Europe's oceans and seas and promote maritime heritage (European Commission 2011). It contains over 40 spatial layers of information covering 10 different thematic areas (e.g. transport, fisheries) for the whole of the European Union, some of which link to additional contextual and educational information. The Atlas also links to a number of national atlas web sites. At a national level, CWAs such as DKO were developed to raise awareness of coastal issues among a very broad audience including the general public. Given the popularity and success of the printed version of the DKO it is now being implemented as a CWA (Maelfait and Belpaeme 2009).

As well as being a data repository, the MIDA plays a significant role in teaching and training at University College Cork. As part of a technology Masters course it is used to teach the principles of web GIS development and metadata management. Students in a coastal management course use it as a source of data and information for their assignments and projects. The Atlas team has also employed ten national and international postgraduate students as trainees for periods varying from 3 to 12 months to contribute to data layer creation and update as well as compilation of information pages. This has given the students hands-on training in spatial data management and the practical issues surrounding CWA development and maintenance (Dwyer et al 2010).

Atlases are generally designed to meet the basic needs of a broad range of users, but are sometimes too complicated for general audiences. In some cases users can be empowered by the interactive nature of CWAs, many of which provide easy tools and additional online resources to allow them to explore topics in more depth, whilst in others atlases may not provide enough functionality for professional audiences. Existing CWAs offer visualization and simple interrogation of datasets with limited functionality for analysis and value added outputs. Developers should consider designing multiple versions which provide a range of services to make a system accessible to both the public and professionals. Users need robust, reliable systems that deliver up to date data and information in a format that meets their skill level and interest. Sometimes a simpler atlas is more effective than one with a lot of functionality. Consultation with the user community throughout the design phase is vital to ensure development meets their needs.

CWA tools can be developed to meet the needs of a specific audience. The Washington Coastal Atlas has a shoreline photo viewer which contains oblique photos of Washington's entire coastline from multiple years. This tool allows coastal managers to investigate easily coastal development over time for a particular area. This tool is also popular among the general public (Washington State Department of Ecology 2011).

The emergence of Google Earth and other virtual global viewers has revolutionised public expectations with respect to geospatial data visualisation. While they currently do not have the same level of geospatial functionality of a GIS, developers and the user community are continually developing features to enhance these tools (Green et al*.,* 2007). The strong visual element and the ease of use of such viewers is setting a *de-facto* standard with respect to spatial data presentation.

Methods for providing additional CWA services should continually be explored as web-based technologies improve and data becomes more widely available. The impact of global viewers on CWA development and the potential to work with or incorporate elements of them in next version CWAs need to be considered. The next generation of CWAs need to extend beyond basic interactive map visualisation systems and offer a suite of analysis tools and value added outputs, such as those emerging in the Marine Spatial Planning domain (McClintock 2009). Nonetheless it is also vital to balance the exploration and implementation of new approaches and technologies against maintaining a stable and functioning system.

Atlas Technologies and Standards

Workshop outcomes demonstrate that CWA developments in the United States and Europe are using similar technologies and standards. CWAs are using cutting edge technology to develop effective atlases which provide access to a wide variety of content, including geospatial data and metadata, text, documents and imagery. A number of proprietary and open source software are being used in combination to meet the demands of complex system design for data preparation, web mapping, database management and web services to find the most effective and efficient methods for CWA development and management. Developers must be aware of the latest information on the various standards and specifications and strive towards their implementation in their products. For example, the utility of technologies such as XML, GML, geoRSS and content management systems can be used to help in the development process. However there needs to be a balance between improving technology with maintaining and updating existing systems.

CWA developers and data owners on both sides of the Atlantic are also implementing international standards for data, metadata and technology and looking towards a future of distributed networks to reduce data duplication. Consolidation of international standards and specifications is making atlas development easier. The ISO 19115/19139 metadata standards are now being adopted worldwide and will enhance exchange between geographic metadata catalogues. The FGDC metadata standard in the US has been in place for a number of years and has proven to be useful in collaborative efforts, such as with the Oregon Coastal Atlas. National metadata standards, such as the FGDC, are now being aligned with the ISO standard (FGDC 2006). Further work can be done to encourage data owners to adequately document their data and ensure their metadata meets appropriate standards. Other standards such as the World Wide Web Consortium (W3C) facilitate development of GIS client interfaces. Open source and Open Geospatial Consortium standards facilitate re-use of code and enhance data sharing, presentation and the development of advanced tools. WMS and WFS protocols allow interoperability between distributed data servers. Also, Digital Object Identifiers (DOI) may be of use in linking data to metadata. Many CWAs are moving towards becoming OGC compliant and implementing distributed networks.

Database management systems (DBMSs) are crucial for efficient content management. Some existing CWAs use DBMSs to varying degrees to keep track of metadata, data and associated information. As spatial data volumes increase, their management and delivery become more difficult. CWAs can require a significant amount of time to add and update content manually. Users require fast response times, so it is imperative that CWA developments can keep pace with such requirements. Network capacity may also need to be addressed in innovative ways. Improvements are necessary to develop and implement efficient, flexible and easy to use database management systems for improved content management.

Considerations for CWA Development

Coastal web atlas developers must take into consideration many factors in order to design an effective CWA, ranging from software and technology to data content and atlas focus. Issues, such as atlas design and usability, technology, data content, available resources and meeting user needs, must be well thought-out before and during development. The design and usability of an atlas are keys to its success. An atlas should clearly communicate its purpose, be visually appealing, be kept as simple as possible, use efficient technology and management systems and have a flexible design to enable growth and change over time. Ultimately its success relies on the atlas users, so efforts should be made regularly to ensure that it meets the needs of those users. An outcome of the workshop was an extensive list of development considerations for the design and implementation of a CWA and its components, which are given in more detail in the Workshop Report (O'Dea et al. 2007).

It is imperative to invest sufficient time at the beginning of an atlas project to designate clear goals and to identify how best to achieve those goals. There are a number of critical questions to address, such as: who is the audience and what are their skills and interests?; will it be a tool specifically for coastal practitioners or for a much broader audience?; what resources are available for development and maintenance?; what data and information should be included?; what technology and standards should be used?; how will the system and its content be managed?; and how will the atlas be sustained and updated in the long term? A cost-benefit analysis should be performed that takes into consideration the cost of web mapping and database software (both proprietary and open source) as well as the programming and maintenance resources which are required in both the short and long terms. The level of functionality needed may influence the software chosen for the atlas. For example, advanced mapping tools may be more easily supplied by a popular, but expensive, proprietary software.

Atlas developers should be aware that geospatial data and metadata collection and preparation are resource and time intensive. Creating a Memorandum of Understanding for data suppliers to document agreed terms for proprietary data can ensure that permissions to make data available online and particular requests, such as specific symbology, restricted attributes and copyright statement, are well documented. When adding data to a web GIS, it is important to be aware of and find ways of minimising potential misinterpretation when layers created at greatly different scales are viewed together. Metadata is crucial to geospatial data management when bringing together and sharing data from a variety of sources, however it is not always available and may require extra work, including discussion with data owners, to collect a minimum level of metadata for each dataset to meet atlas needs. This minimum level should be a subset of core metadata elements which meet a standard, such as ISO 19115 or FGDC. A metadata search tool which enables users to search for data by various qualities (such as by title, keyword, date, area) is invaluable, particularly for professionals seeking data.

In the atlas design process it is worthwhile to invest time examining different existing web GIS to get ideas and determine certain features to integrate or avoid. Thought should be given to designing a flexible system which is sustainable and able to handle changing technology, as well as scalable so that it can grow beyond current expectations. A flexible web interface, such as one that provides a choice of multiple map page formats and a variety of ways to view geospatial data, can help to accommodate different audiences' skill levels. Advanced map tools may not be necessary for some users and may complicate the interface. During the atlas development process it is crucial to acquire regular user feedback (e.g., hands-on workshops, surveying across user groups), which can ensure that the atlas design and data content is appropriate and help to provide focus for the next development steps. In order to manage atlas content, such as data layers, metadata and information efficiently, it is worthwhile investing time in the development of a customised scalable database management system, which will help to minimise time required to add and update atlas content regularly.

The success of an atlas is not limited to the design of the system and its components. Other factors must also be taken into consideration to ensure atlas success. Atlas owners should be open to collaboration, for example, in sharing data via distributed systems or in sharing technology and ideas with other developers. It is critical to look beyond funding for initial atlas development from the outset and seek funding for site maintenance and extending atlas content and functionality. Atlas promotion and dissemination through various resources is important to do regularly in order to bring in new users and to remind past users that the atlas is current and alive.

Institutional Capacity

New legislation and policies are driving the production of quality coastal datasets and improved data availability. High quality spatial data underpins much of the policy implementation required by government. For example, LIDAR elevation data in coastal areas can be used to help identify coastal erosion and flooding risk. Freedom of Information legislation and coastal and marine policy for the European Union and the US are requiring government organisations to improve the visibility and accessibility of public sector information. CWAs are an effective way to help in the implementation of such legislation. The CWA community must provide input to policy development to help raise awareness of issues of relevance to coastal GIS communities, including the importance of data accessibility. Methods for effective outreach to decision makers must be improved in order to gain atlas support from high levels.

The erratic nature of funding can compromise maintenance and ongoing CWA development. In some cases CWAs are grant funded for initial development, however they risk going out of date due to the lack of resources for site maintenance beyond the initial development stage. This can undermine both user and data supplier confidence. In other cases atlases are funded indefinitely by an institution or network of partners. Funding is often tied to innovation and technology developments rather than user requirements and data delivery and updates. The uncertainty surrounding funding can also lead to loss of expertise and personnel from projects. After initial proof of concept projects, there is a need to fund atlases on a long-term basis in order to guarantee their stability. Different financial models need to be examined to determine the best methods for continued CWA support. Consideration should be given to ideas such as obtaining multiple funding sources, sponsorship by key organisations, providing paid subscriber only areas for advanced functionality, or developing spinoff initiatives, such as the publication of a CWA in print media.

There is limited capacity to measure the impact of CWAs in the coastal community. Web statistic software enables site managers to study atlas usage by various means, such as the number of unique visitors, the number of pages visited and the files which are downloaded. However this information only tells part of the story. There are limited means to measure impacts which are difficult to quantify. For example, how to measure: the convenience of quick access to data which users would have previously had to acquire themselves; the benefits of providing a holistic view among the science community; and the value of clearly communicating coastal issues to the general public. The Marine Overlays on Topography (MOTIIVE) project, which tested land-sea data harmonisation and interoperability standards set out by the EU INSPIRE Directive, investigated a number of cost-benefit methodologies. They used a multi-criteria analysis to look at topics such as direct user value/benefit, social value, operational benefits and financial values to institutions and strategic political value (Longhorn 2007). Such an approach may be valuable to help measure impacts of CWAs in coastal communities.

Ongoing dissemination and publicity of CWAs is important to atlas success. CWA publicity may be limited to landmark events such as launches or development of new tools. However, it is important not to oversell the ability of atlases or to make unrealistic claims. Outreach events raise awareness of a CWA and increase the number of users. Regular methods and creative options should be explored for frequent and effective outreach. Email lists keep users informed of developments and ongoing maintenance of a CWA. Press publicity and appearances at events and conferences increase exposure. Awareness can also be raised by brochures and innovative giveaways (e.g., postcards and calendars). Maintaining momentum is important to increasing the audience base. The CWA community needs to develop and share further innovative ideas.

The emergence of various CWAs has resulted in a concomitant growth of expertise in the area of online CWA design and presentation. Collaboration among researchers is now being actively supported following on the establishment of an International Coastal Atlas Network (ICAN) (http://icoastalatlas.net) which has been one of the major outcomes of this workshop series. The long-term strategic aim of ICAN is to share knowledge and experience among atlas developers in order to find common solutions for coastal web atlas development whilst ensuring maximum relevance and added value for the users (Wright et al., 2010). A specific goal of the Network is to encourage and help facilitate the development of digital atlases of the global coast based on the principle of distributed, high-quality data and information. A prototype which demonstrates integration of different heterogeneous and autonomous atlases has been built as part of ICAN's activities (Lassoued et al., 2010)

Conclusions

This workshop demonstrated that Coastal Web Atlases are a key tool for the delivery of spatial data, information and maps to support better coastal and marine area management and governance. CWAs have developed over the last decade from being simple, centralised repositories of data and information to distributed systems accessing data on multiple servers and providing interactive tools using the most recent visualisation technologies. They are emerging as important tools in regard to marine spatial planning, where decision support systems incorporate web GIS mapping functionality. However challenges exist with regard to data, design, technology and institutional capacity. These will have to be addressed if we are to optimize decision making in regard to the coast at a variety of levels and across themes. New legislation and policies such as the West Coast Governors' Agreement on Ocean Health in the US and European Union's actions on Marine Spatial Planning recognize the need for tools such as CWAs. The International Coastal Atlas Network which emerged as a result of this workshop provides a collaborative forum, comprising both atlas developers and users, in which these challenges can be addressed. The network now comprises of more than 35 member organisations in 14 countries who are involved in technical development, outreach and training and awareness raising activities for CWAs. Membership includes the atlas developers mentioned in this article, but also International bodies such as the European Environment Agency, the International Oceanographic Data and Information Exchange Office and the Coastal Services Center of the National Oceanic and Atmospheric Administration. These bodies recognise the potential interoperable marine information systems can play in providing operational services for practitioners and users across the world.

Acknowledgements The authors thank the U.S. National Science Foundation, the Marine Institute of Ireland's Marine RTDI Networking and Technology Transfer Initiative under the National Development Plan and the Coastal & Marine Resources Centre of University College Cork for their financial support. The authors also wish to gratefully thank workshop participants for their contributions, including representatives from: the British Oceanographic Data Centre; CEDaR, the Centre for Environmental Data & Recording, Ulster Museum; Centre for Coastal & Marine Research, University of Ulster, Coleraine; Coastal & Marine Resources Centre, University College Cork; Coordination Centre for Integrated Coastal Zone Management of Belgium; Department of Communications, Energy and Natural Resources; Environment & Heritage Service; European Environment Agency Topic Centre on Terrestrial Environment; Geological Survey Ireland; Geosciences Dept., Oregon State University; Inst. for Natural Resources, Oregon State University; Marine Institute of Ireland; UK Maritime and Coastguard Agency; Memorial University Newfoundland; NOAA Coastal Services Center; Oregon Ocean-Coastal Management Program; San Diego Supercomputer Center; Scripps Institution of Oceanography, University of California, San Diego; Strangford Lough Management Committee; and Virginia Institute of Marine Science.

References

Belpaeme K, Konings Ph (eds) (2004) The Coastal Atlas Flanders-Belgium. The Co-ordination Centre for Coastal Zone Management: Ostend, Belgium. 100 pp.

Belpaeme K, Maelfait H (2010) Belgium. In: Wright DJ, Dwyer N, Cummins V (eds) Coastal Informatics: Web Atlas Design and Implementation, IGI Global, pp 156-164

Berman M, McCall C (2010) Virginia and Maryland, USA. In: Wright DJ, Dwyer N, Cummins V (eds) Coastal Informatics: Web Atlas Design and Implementation, IGI Global, pp 131-144

Clinton WJ (1994) Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure. Executive Order 12906. United States Federal Register 59: 71. April 11. 4pp. http://www.archives.gov/federal-register/executive-orders/pdf/12906.pdf. Accessed 6 January 2011

Co-ordination Centre for Integrated Coastal Zone Management in Belgium, Province of West-Flanders, Flemish Government: Nature and Coastal Defence Department, Flanders Marine Institute (VLIZ), Environmental Department, Federal Government (2008) De Kustatlas Online. http://www.kustatlas.be. Accessed 6 January 2011

Department of Environment, Food, and Rural Affairs (DEFRA) (2002) Delivering Integrated Marine Mapping for the UK: Report of DEFRA-funded workshop held at Church House, London, 11 September 2002, compiled by F.L. Franklin, DEFRA, Burnham Laboratory.

Department of Environment, Heritage and Local Government (2004) Irish Spatial Data Infrastructure Consultation Document. http://www.irishspatialstrategy.ie/isdi/. Accessed 6 January 2011

DEFRA (2006) Coastal and Marine Resource Atlas - Final Report. 36pp. http://www.magic.defra.gov.uk/Me1302_4030_FRP.pdf. Accessed 6 January 2010

Dwyer N, Wright DJ (2008) Report of International Coastal Atlas Network Workshop 3 on Federated Coastal Atlases: Building on the Interoperable Approach. European Environment Agency, Copenhagen, Denmark. http://ican.science.oregonstate. edu/ican3_final_rpt Accessed 6 January 2011

Dwyer E, Kopke K, Cummins V, O'Dea L, Dunne D (2010) Ireland. In: Wright DJ, Dwyer N, Cummins V (eds) Coastal Informatics: Web Atlas Design and Implementation, IGI Global, pp 105-130

European Commission (2003) Directive 2003/98/EC of the European Parliament and of the Council of 17 November 2003 on the Re-use of Public Sector Information. Official Journal of the European Union Communities: L 345/90. Dec. 31. 7pp. ftp://ftp.cordis.europa.eu/pub/econtent/docs/acte_en.pdf. Accessed 6 January 2011

European Commission (2007) An Integrated Maritime Policy for the European Union. Commission of the European Communities. Brussels, 10 October 2007, COM(2007) 575 final. 16pp. http://eur-lex.europa.eu/LexUriServ/site/en/com/2007/com2007_0575en01.pdf. Accessed 6 January 2011

European Commission (2010) Maritime Spatial Planning in the EU – Achievements and Future Development, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM (2010) 771 final 11pp. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0771:FIN:EN:PDF . Accessed 6 January 2011

European Commission (2011) European Atlas of the Seas. http://ec.europa.eu/maritimeaffairs/atlas/index_en.htm. Accessed 6 January 2011

European Parliament (2000) Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000, Establishing a Framework for Community Action in the Field of Water Policy. Official Journal of the European Union Communities: L 327/1. Dec. 22. 72pp. http://eur-lex.europa.eu/LexUriServ/site/en/oj/2000/l_327/l_32720001222en00010072.pdf. Accessed 6 January 2011

European Parliament (2007) Directive of the European Parliament and of the Council establishing an Infrastructure for Spatial Information in the European Community (INSPIRE). PE-CONS 3685/2006. January 17. Brussels. http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//NONSGML+JOINT-TEXT+C6-2006-0445+0+DOC+PDF+V0//EN&language=EN. Accessed 6 January 2011

Federal Geographic Data Committee (FGDC) (2006) FGDC ISO Metadata Standard Activities. http://www.fgdc.gov/metadata/fgdc-iso-activities. Accessed 6 January 2011.

Global Spatial Data Infrastructure (2004) Developing Spatial Data Infrastructures: The SDI Cookbook. Nebert DD (ed). Version 2. 25 January. 171pp.

Goodchild MF, Fu P, Rich P (2007) Sharing geographic information: an assessment of the Geospatial One-Stop. Annals of the Association of American Geographers. 97(2): 249–265.

Green DR, Carlisle M, Mouatt J (2007) Constructing a Local Coastal GIS, Virtual Fieldtrips, and Virtual Reality Simulations Using Google Earth. CoastGIS 07 Conference Proceedings. 1:224-234. Santander, Spain.

Haddad TC, Wright DJ, Dailey M, Klarin P, Marra J, Dana R, Revell D (2006) The tools of the Oregon Coastal Atlas. In: Wright DJ, Scholz A (eds), Place Matters: Geospatial Tools for Marine Science, Conservation and Management in the Pacific Northwest. Corvallis, OR: Oregon State University Press, pp134-151. http://dusk.geo.orst.edu/placematters/7-OCA_Tools_preprint.pdf. Accessed 6 January 2011

Haddad TC, Bailey RJ, Wright DJ, (2010) Oregon. In: Wright DJ, Dwyer N, Cummins V (eds) Coastal Informatics: Web Atlas Design and Implementation, IGI Global, pp 91-104

Institute for Natural Resources (2005) North Coast Basin Prototype Website Project Completion Report. Feb. 28. 30pp. http://oregonstate.edu/inr/inr-2005-1. Accessed 6 January 2011
Institute for Natural Resources, Oregon State University Libraries (2011) North Coast Explorer, Oregon. http://oregonexplorer.info/northcoast/. Accessed 6 January 2011
International Oceanographic Data and Information Exchange (2011) http://www.caribbeanmarineatlas.net/, Caribbean Marine Atlas. Accessed on 6 January 2011
Juda L (2005) The report of the U.S. Commission on Ocean Policy: State perspectives, Coastal Management, 34(1): 1-16, doi:10.1080/08920750500364930
Lassoued Y, Pham TT, Bermudez L, Stocks K, O' Grady E, Isenor A, Alexander P (2010) Coastal Atlas Interoperability. In: Wright DJ, Dwyer N, Cummins V (eds) Coastal Informatics: Web Atlas Design and Implementation, IGI Global. pp 53-78
Lavoi, T., Murphy J, Sataloff G, Longhorn R, Meiner A, Uhel R, Wright DJ, Dwyer E (2010) Coastal Atlases in the Context of Spatial Data Infrastructures, In: Wright DJ, Dwyer N, Cummins V. (eds) Coastal Informatics: Web Atlas Design and Implementation, IGI Global. pp 239 – 255
Longhorn RA (2007) Marine Overlays on Topography (MOTIIVE) and the EU INSPIRE Directive. CoastGIS 07 Conference Proceedings. 1:150-160. Santander, Spain.
Longhorn R, Blakemore M (2004) Re-visiting the Valuing and Pricing of Digital Geographic Information. Journal of Digital Information,4 (2). Article No. 250
Maelfait H, Belpaeme K (2009) The Belgian Coastal Atlas: moving from the classic static atlas to an interactive data-driven atlas. Journal of Coastal Conservation DOI 10.1007/s11852-009-0076-5
Maelfait H, Belpaeme K, Lescrauwaet AK, Mees J (2006) Indicators as reliable guides for Integrated Coastal Zone Management, In: Forkiewicz M (ed), Integrated Coastal Zone Management: Theory and Practice. EuroCoast - Littoral 2006, pp180-186. http://ioc3.unesco.org/marinesp/files/Indicators%20for%20Belgian%20ICZM.pdf. Accessed 6 January 2011
Marine Institute, Geological Survey of Ireland, Environmental Protection Agency, Coastal and Marine Resources Centre and Department of Communications, Energy and Natural Resources (2011) The Irish Spatial Data Exchange. http://www.marine.ie/isde/. Accessed 6 January 2011
Maritime and Coastguard Agency, Department of Environment, Food and Rural Affairs, Scottish Executive, Scottish Natural Heritage, Energy Institute, Joint Nature Conservation Committee, Environment Agency, English Nature, Department of Trade and Industry, Hampshire County Council, Essex County Council, Kent County Council and British Geological Survey (2011) The Coastal and Marine Resource Atlas. http://www.magic.defra.gov.uk. Accessed 6 January 2011
McClintock W. (2009) New Web-Based Tool Allows Planners to Design MPAs, View Potential Impacts Instantly. In MPA News 10 (8): p 4 http://marinemap.org/news/mpa-news-article-on-marinemap. Accessed 6 January 2011
Meiner A (2010) Integrated Maritime Policy for the European Union – Consolidating Coastal and Marine Information to Support Maritime Spatial Planning , Journal of Coastal Conservation, DOI 10.1007/s11852-009-0077-4
Millard K, Sayers P (2000) Maximising the use and exchange of coastal data. A guide to best practice, CIRIA, London, ISBN: 978-0-86017-541-4 pp.96
MMI (2011) Marine Metadata Interoperability Project. http://marinemetadata.org/. Accessed 6 January 2011
O'Dea L, Dwyer E, Cummins V, Dunne, D, Ó Tuama É (2004) Improving Access to Coastal Information: Metadata in the Marine Irish Digital Atlas. ECO-IMAGINE Conference Proceedings. Seville, Spain. May. 10pp.
O'Dea L, Cummins V, Wright D, Dwyer N, Ameztoy I (2007) Report on Coastal Mapping and Informatics Trans-Atlantic Workshop 1: Potentials and Limitations of Coastal Web Atlases. University College Cork, Ireland http://workshop1.science.oregonstate.edu/final_rpt. Accessed 6 January 2011
Oregon Ocean-Coastal Management Program, Oregon State University, Ecotrust (2011) The Oregon Coastal Atlas. http://www.coastalatlas.net. Accessed 6 January 2011
Pew Oceans Commission (2003) America's Living Oceans: Charting a Course for Sea Change. A Report to the Nation. May 2003. Pew Oceans Commission, Arlington, Virginia.
Scott L., Reed, G. (2010) Africa. In: Wright DJ, Dwyer N, Cummins V (eds) Coastal Informatics: Web Atlas Design and Implementation, IGI Global. pp 165 – 170
State of California, State of Oregon, State of Washington. (2010) West Coast Governors' Agreement on Ocean Health, http://westcoastoceans.gov/. Accessed 4 January 2011
United Nations Population Fund (2007) State of World Population 2007 – Unleashing the Potential of Urban growth, UNFPA, New York, http://www.unfpa.org/swp/2007/. Accessed 6 January 2011
University College Cork, University of Ulster (2011) The Marine Irish Digital Atlas. http://mida.ucc.ie. Accessed 6 January 2011

US Congress (2000) Coastal Zone Management Act of 1972 [As Amended Through P.L. 106–580, Dec. 29, 2000]. Sec. 301. Dec. 29. 30pp. http://epw.senate.gov/czma72.pdf. Accessed 6 January 2011

US Congress (2002) The Freedom of Information Act: 5 U.S.C. § 552 [As Amended in 2002]. Dec. 23. http://www.justice.gov/oip/04_7.html. Accessed 6 January 2011

Virginia Institute of Marine Science (2011) Mapping Tools for Coastal Management. http://ccrm.vims.edu. Accessed 6 January 2011

Washington State Department of Ecology (2011) Washington State Coastal Atlas. http://www.ecy.wa.gov/programs/sea/sma/atlas_home.html. Accessed 11 January 2011

Weihrich H (1982) The TOWS Matrix – A Tool for Situational Analysis. Long Range Planning, 15(2): 54-66.

Wright DJ (2004) The New “Explornography” in the Age of Digital Earth, Digital Government, and Cyberinfrastructures. GIS Ireland 2004 Conference Proceedings. Irish Organisation for Geographic Information. Dublin.

Wright DJ, Cummins V, Dwyer E (2010) The International Coastal Atlas Network. In: Wright DJ, Dwyer N, Cummins V (eds) Coastal Informatics: Web Atlas Design and Implementation, IGI Global. pp 229-238