NICHOLAS SCHOOL OF THE ENVIRONMENT AND EARTH SCIENCES
DUKE UNIVERSITY

DUKE UNIVERSITY MARINE LABORATORY

July 17, 2007

Mr. Jesse Ausubel
Program Director
Alfred P. Sloan Foundation
Suite 2550
630 Fifth Avenue
New York, NY 10111-0242

Dear Mr. Ausubel:

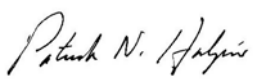
We are very pleased to submit our proposal, *"Implementing consistent and effective geospatial analysis, mapping and visualization across the Census of Marine Life: Development of the CoML mapping & visualization coordination team".* This proposal outlines the proposed development of a new initiative to develop *compelling, intuitive, accurate* and *consistent* mapping and visualization products across the Census programs and field projects. This proposal is specifically designed to support the development of maps and visualization products leading up to release of "The First Census of Marine Life" in October 2010.

We have coordinated the tasks of this proposal to work in tandem with the Education and Outreach program. Both of our groups are asking for a 27 month work period beginning in October 2007 to allow us to begin work as soon as possible. We feel that it will be critical to begin this effort in Fall of 2007 so that our proposed program will be operational prior to the *"All Programs"* meeting in November as well as have sufficient lead time to develop organize our first mapping and visualization workshop in spring 2008.

With this proposal we specifically target the *technical development*, *technology transfer*, *training* and *support needs* required to advance the capabilities of individual Census projects and the synthesis of the Census outcomes as a whole. Our proposal is based on three important activities (1) Develop a common mapping and visualization framework; (2) Develop technical workshops and training efforts and (3) Develop a continuing support effort to promote the adoption of effective mapping and visualization techniques. An additional role we propose to play is to act as a central technical liaison with emerging mapping and visualization partners such as the National Geographic Society, Google Oceans, and ESRI as well as other mapping and visualization specialist organizations.

We look forward to working with the Alfred P. Sloan Foundation and the CoML-SSC on refining this effort to best meet the needs of the Census.

Sincerely,



Patrick N. Halpin
Gabel Associate Professor of the Practice of Marine Geospatial Ecology
and Director of the Geospatial Analysis Program
Nicholas School of the Environment and Earth Sciences
Duke University
Durham, NC 27708-0328

Development of the Census of Marine Life

Mapping & Visualization Coordination Team

July 17, 2007

A proposal submitted to the Alfred P. Sloan Foundation

Patrick N. Halpin
Gabel Associate Professor of the Practice of Marine Geospatial Ecology
Marine Geospatial Ecology Lab
Nicholas School of the Environment and Earth Sciences
Duke University Marine Lab

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Context

The need to communicate effectively to a wide range of audiences is a fundamental goal of the Census of Marine Life. Expanding our ability to synthesize, map and visualize the process of exploration, the broad extent of our data collections, and the analytical findings from each Census project is critical to the success of the entire Census endeavor. Creating *compelling*, *intuitive*, *accurate* and *consistent* mapping and visualization products is essential to communicating the message of each Census project to the scientific and popular media. To better achieve these fundamental goals we need to proactively develop and implement common geographic and visualization tools and methods as we prepare for the public presentation of the first Census of Marine Life in 2010.

The ocean environment provides challenges and exciting opportunities for the presentation of Census results. The unique three-dimensional and dynamic nature of the ocean realms requires fundamentally more sophisticated methods of visualization than the static, two-dimensional maps and visualization methods commonly used to represent the terrestrial world. This challenge also provides a tremendous opportunity for Census projects to create novel, visually engaging presentations of ocean data and exploration activities. Our collective ability to capture attention and increase the visibility of the Census and its mission depend directly on the ability to effectively present our results. Because we can not directly visualize much of the ocean realm, it is incumbent on us to develop the necessary geographic information system tools, scientific visualizations and multimedia products to make the results of the Census vivid and engaging. This need to recreate the functional relationships of the undersea realm in a

virtual environment is a necessary component of our charge to present the discovery of the oceans to the global public.

While most individual Census researchers necessarily generate maps, scientific figures and other depictions of their research efforts, the Census has not yet developed a program to proactively standardize the mapping and visualization capabilities of individual projects into a coordinated and consistent media. With this proposal we specifically target the *technical development*, *technology transfer*, *training* and *support needs* required to advance the capabilities of individual Census projects and the synthesis of the Census outcomes as a whole. We specifically outline a work-plan for the development of a “Mapping and Visualization” coordination team to advance the mapping and visualization capabilities of each Census projects as well as promote common tools, protocols and standards to create a more unified and consistent presentation of the entire Census effort. While developing the abilities of the separate projects will work to advance the message of each individual effort, developing a common framework of software tools, protocols and standards will be essential to telling the message of the Census as a whole.

In preparation for the public presentation of the “First Census of Marine Life” in 2010, a series of planning and management efforts where initiated in 2006-2007. A “Framework” committee was formed to explore new directions and help set priorities for the culmination of the first Census efforts in 2010. The development of consistent, high-impact mapping and visualization products and media across all census programs and projects was a significant priority of the Framework Committee’s findings:

"Through a combination of an internal mapping and visualization development program and the nurturing of new partnerships, the Census can move to more proactively advance our mapping and visualization capabilities. By developing a mapping and visualization development program we will encourage shared tool development, the establishment of standards, protocols, training workshops and ongoing support services." *(Seven Seas, One Ocean: Final Report from the Census of Marine Life Framework Committee)*

The CoML Scientific Steering Committee is in the process of organizing an emerging Synthesis Committee as well as a coordinated group of "Synthesis Management Teams" to lead and coordinate the implementation of CoML efforts leading up to 2010. In addition to the existing CoML Secretariat and Education and Outreach teams, the development of a new "Mapping and Visualization" coordination team was identified as a necessary component for synthesis efforts (Figure 1). In this proposal we outline the goals, development and operation of this new effort as well as detail the expected relationship of the proposed "Mapping and Visualization" team to other management and project level activities of the Census.

Project

This project aims to facilitate the development and display of consistent, sophisticated geospatial and visualization products across the Census of Marine Life (CoML) in anticipation of the 2010 rollout. The CoML Mapping and Visualization (M&V) team at Duke's Marine Geospatial Ecology Lab (MGEL) will provide technical assistance for projects, particularly for those lacking sufficient in-house resources, and promote a common look and feel for mapped and visual products from individual CoML projects. The resulting products will be both static maps and graphics for print publication as well as multimedia, such as interactive online maps and animations.

Role and Partnerships

While the Marine Geospatial Ecology Lab at Duke University will provide the nucleus of the Mapping & Visualization team, one of our first tasks will be to expand the team to include additional expert participants from representative Census projects. We feel strongly that expanding the participation in the core team will produce a wider diversity of expertise and perspective and help increase further participation across the entire Census program. We are planning to solicit active participation from representatives from at least three additional project teams to serve on the M&V team. To this end we have allocated a modest amount of funds specifically to be used to support participation of core team members from other Census projects. We plan to work closely with the Synthesis Team and Scientific Steering Committee in the selection of these key players at the onset of this project.The primary clients of this project will be the scientific investigators, outreach and technical staff from within the Census, developing the visual products that they will use to communicate to a wider audience. Identification of

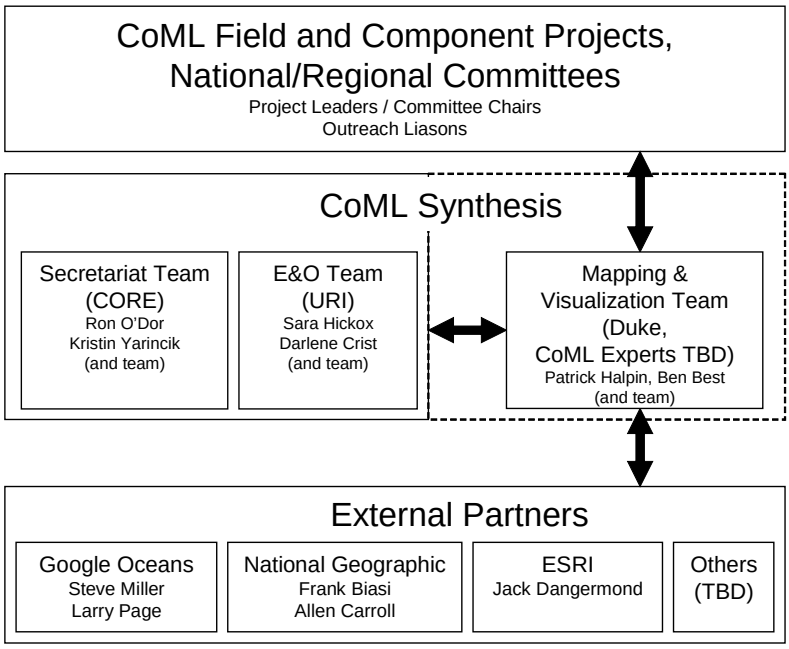


Figure 1. The Mapping and Visualization Team at Duke will coordinate the mapping and visual products between the high-level CoML synthesis entities, individual CoML projects and committees, and the industry partners for technology use and promotion.

primary technical mapping and visualization representatives as well as outreach contacts from each project will be an essential first step we will complete at the onset of this project. We expect that the primary technical contacts will also serve as the primary points of contact to other members of their respective project teams. In addition to technical representatives we will identify appropriate outreach and media representatives from each of the Census programs and field projects. We plan to work directly with each project and in coordination with the Education & Outreach (E&O) team in the selection of appropriate education and outreach representatives. We plan to begin this critical team building phase immediately in Fall 2008, so that we can have initial representatives identified prior to the “All Programs” meeting scheduled for November 2008.

The role of the Mapping and Visualization team is to not only look inwards in developing technical relationships with members of the Census project teams, but also to serve as the technical liaison to mapping and visualization activities outside of the Census. This important liaison role will build on existing relationships with key organizations and industry partners. Technical expertise and promotional capabilities will be drawn from partnerships with industry partners, including Google, National Geographic and ESRI. The CoML M&V team will act as technical liaison for visual data exchange between the various CoML field projects, higher level CoML synthesis teams, and industry partners (Figure 1). Existing visualization and mapping experts from within the CoML will be solicited for supporting this effort by sharing tools and experience with small contracts. Members of the proposed Mapping and Visualization Team have ongoing working relationships with a number of organizations that will likely play critical roles in the

development of different aspects of mapping and visualization for the Census during the next two years.

Each organization we approach will offer different expertise and opportunities for collaboration. These emerging collaborations will be important to the development of high quality mapping and visualization products and media. It will be especially important for the Census to carefully define the expected relationship with partner organizations and take care to not create undue overlap between initiatives. In order to illustrate potential roles collaborating organization may take in the development of mapping and visualization for the Census, we will consider three emerging collaborations.

The National Geographic Society

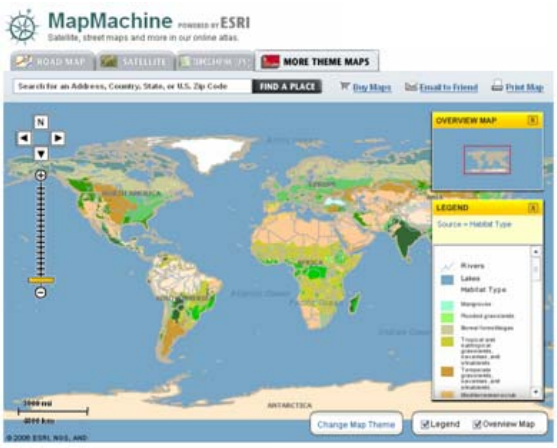


Figure 2. National Geographic Society's interactive online mapper, "MapMachine".

The Census is in early discussions with the National Geographic Society (NGS) concerning the presentation of Census results under a broad range of NGS media outlets. The M&V team has strong existing ties to the Cartography and Digital products teams at NGS and met in June to discuss potential Census collaborations and products. We plan to strengthen this working relationship in close collaboration with the Education and Outreach team. The M&V team is poised to work directly with NGS on the development of selected high-visibility mapping and visualization products. One such product under early discussion could be a "Digital

Atlas of Marine Life" *(pers. comm. Halpin & Biasi, NGS Director of Conservation Mapping)* to be developed collaboratively and hosted by NGS. Other thematic projects could be developed under this type of collaboration. Leveraging the technical and promotional capabilities of the NGS is anticipated to be of great benefit to the Census.

Google

A second collaborative venture under discussion concerns the development of a "Google Oceans" initiative to expand the functionality of the popular Google Earth display interface to include true three-dimensional mapping, high-resolution bathymetric data, oceanic imagery and new functionality as well as appeal to the needs of the ocean research, exploration and conservation communities. Census investigators Earle, Grassle and Halpin met with Google staff in May and were recently asked to sit on the newly formed Advisory Council for the Google Oceans initiative in a follow-up June meeting. The M&V team will ideally act as technical liaison and point of communications with Google on these future developments. Census participants in the "Google Oceans" initiative will continue to explore mutually beneficial developments. For instance, one low-hanging fruit would be the addition of a CoML layer to be built-into Google Earth as part of its Outreach mission

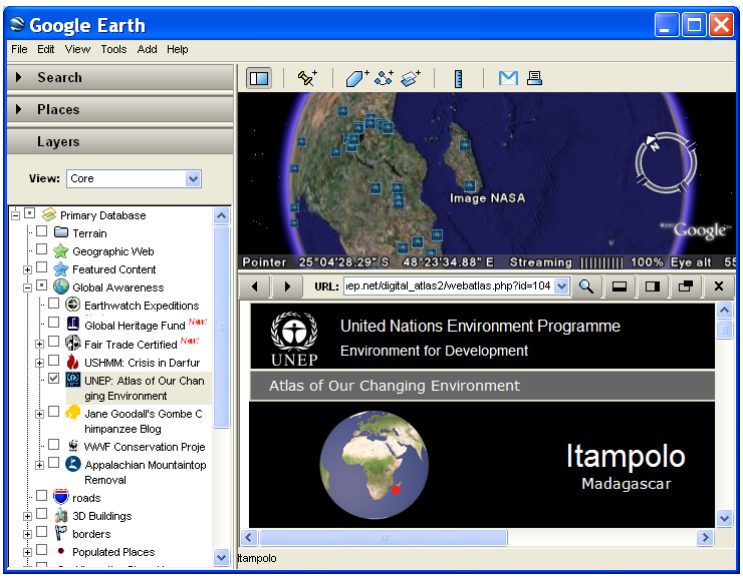


Figure 3. Screenshot of Google Earth showcasing the built-in UNEP Global Awareness layers, part of Google Earth Outreach program.

(http://earth.google.com/outreach), similar to existing UNEP and WWF layers (Moore 2007) (Figure 3).

Besides the popular Google Earth desktop application, Google provides many web services of potential value to the Census effort. Most notably, the Google Map service provides the mapping engine for the current web-based CoML Activities Map (see below). We anticipate exploring additional functionality offered by Google Earth and Google Maps Enterprise engines for scaling up custom Census solutions.

One of the greatest reasons for the popularity of Google services is its open application programming interfaces (API), which are giving rise to many hybrid web applications, i.e. “mashups”. These exploitable APIs are similarly available for Google’s wide range of web services (http://code.google.com/apis). Again, these services should offer great value to the Census, because much of the storage, display and transfer will be handled by Google servers, but will be displayable from within project web sites.

Environmental Sciences Research Institute (ESRI)

A third emerging mapping and visualization collaboration is with the Environmental Sciences Research Institute (ESRI). ESRI is the largest commercial geospatial mapping software firm globally and the ArcGIS software suite is the most commonly used geospatial (GIS) software used by academic, industry, government, and NGO users. CoML investigator Halpin has been working with ESRI on the development of the ArcMarine geodatabase model for marine applications. The latest accompanying book (Wright et al. 2007) uses several Census applications to illustrate marine GIS mapping and visualization (Halpin et al. 2007), exemplified in Figure 4. Some CoML projects are

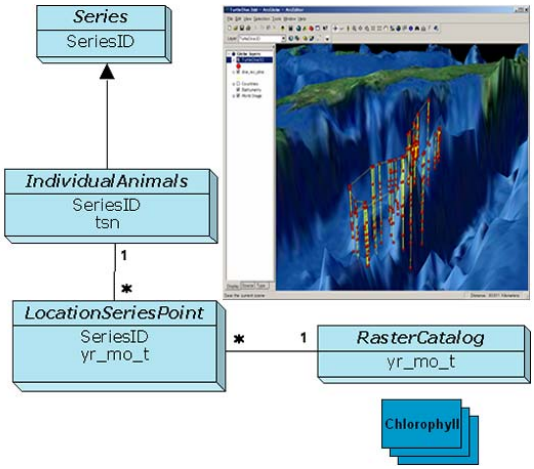


Figure 4. ESRI relational database design elements using ArcMarine geodatabase (Halpin et al. 2007) and inset of interactively visualizing the data in the ArcGlobe 3D application.

already using ArcMarine for managing their animal tracking data (Lord-Castillo et al. 2007). We anticipate providing limited support to other projects who wish to organize their data into a geodatabase, whether using commercial applications from ESRI or open-source alternatives (e.g. PostGIS).

Besides geodatabase development and support, ESRI's products are numerous and comprehensive for GIS display and analysis. One of the most exciting products is the ArcGIS Server, which allows for server-based geoprocessing. For instance we could host place name lookup services, buffer analysis, or environmental envelope modeling. This could enable the M&V team to bear the cost and maintenance of common CoML geoprocessing needs, while individual CoML projects need only the minimal ArcView license or could even use the free ArcExplorer. We will also host web services to provide base-map layers as well as dynamic satellite oceanography harvested from oceanographic archives and converted from scientific data formats to GIS-friendly web accessible data layers.

Other Partners

The three organizations highlighted above represent key groups that we are already collaborating with at this time. We will also be investigating other opportunities with academic institutions, industry and non-profit partners. Based on our needs assessments from workshops and polling involving individual projects and Census-wide

teams, we will strategically target additional technology and groups with the greatest benefit. For example, we plan to work directly with scientific visualization experts such as Colin Ware from UNH (Ware 2004) (Figure 5) as outside experts for our technical workshops and external peer review needs.

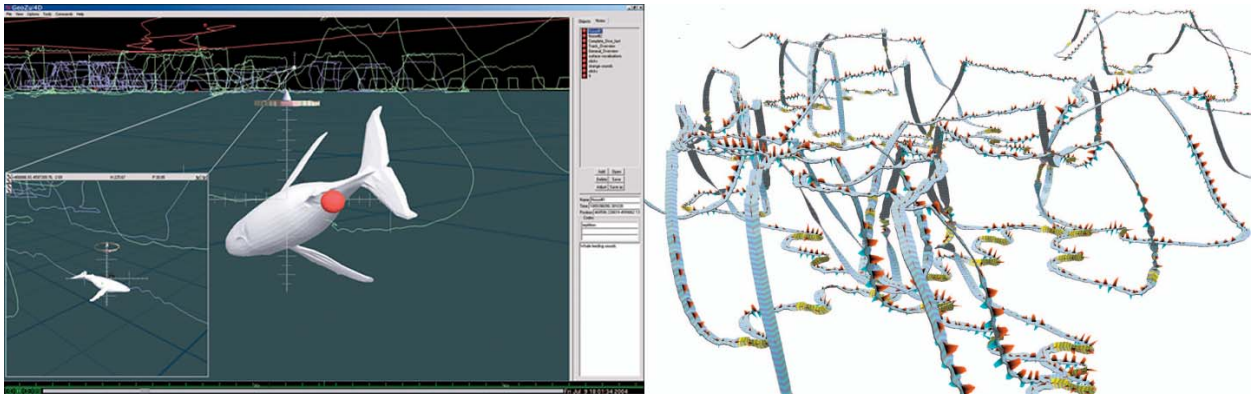


Figure 4. Screenshots of whale tracking visualizations from the GeoZUI4D and TrackPlot applications by Ware et al. (2006).

Census-wide Synthesis

A Common Technical Guide

A common guide to development of visual and mapped products will provide a consistent, high-quality look and feel across the Census. This effort will provide timely technical documentation, software usage suggestions / help, standards, protocols as well as specific templates for mapping and visualization development. A dedicated website (proposed name: www.comlmapvis.org) will serve content on:

- specific mapping standards and protocols,
- collective internet mapping and web-services,
- shared tools and scripts,
- consistent base-map data,
- guides to cartographic standards (digital / print), and
- common templates, color palettes, graphic libraries.

Another goal of the mapping and visualization development program will be to host

focused technical workshops on mapping and visualization. It is important to engage participants from Census projects on issues of effective mapping and visualization early on. The workshops are expected to enlist experts from outside the Census as well as specialists from within the Census with the goal of expanding the technical capabilities of project participants, demonstrating new applications, developing common standards and forming a core mapping and visualization user group across the Census. Topics of the workshop will likely include: technical training on the use of common mapping and visualization environments such as Google Earth/Oceans, web services applications, cartographic considerations, three-dimensional representations of data, spatio-temporal animations and other related topics.

The success of implementing a framework across Census teams and projects will depend upon buy-in within the community. It makes little sense to suggest technology that is insufficient or too complex for individual needs. Yet there is a great range of technical capability and software use across the Census. We intend to provide an array of options to complement this technical diversity. Collecting information on the variety of technologies used and desired additional functionality will be carried out through an initially extensive survey. Communication and feedback will continue in the form of workshops, online polling, email and direct consulting. Assessing user needs will continuously redefine areas of focus for the M&V team throughout the life of this project.

Simultaneously, an assessment will be conducted on the “state-of-the-art” in mapping and visualization software, standards and protocols currently in use and expected to be in common use by the 2007-2010 timeframe. We will be promoting technologies with

the greatest interoperability, long-term viability and lowest cost. While open-source cross-platform tools are generally preferred (e.g. R), commercial packages will be supported that may have enhanced usability and market dominance (e.g. ESRI ArcGIS). We will act in an advisory and support capacity, updating available documentation and tools to be more user-friendly and functional per feedback from CoML members.

Mapping CoML Activities through Time and Space

In order to provide the public with a visual sense of the numerous and widely distributed CoML activities, an interactive mapping interface has already been added to the CoML portal by the CoML M&V team (Figure 6). The various projects are depicted as regions of activity by polygons, cruises as lines, and/or stations as points. Individual spatial features can further include a title, description with external links and temporal lifetime (begin to end). Animations will be generated in the future showing activities flashing on and off through time or just switching on and staying on to fill the globe since CoML inception.

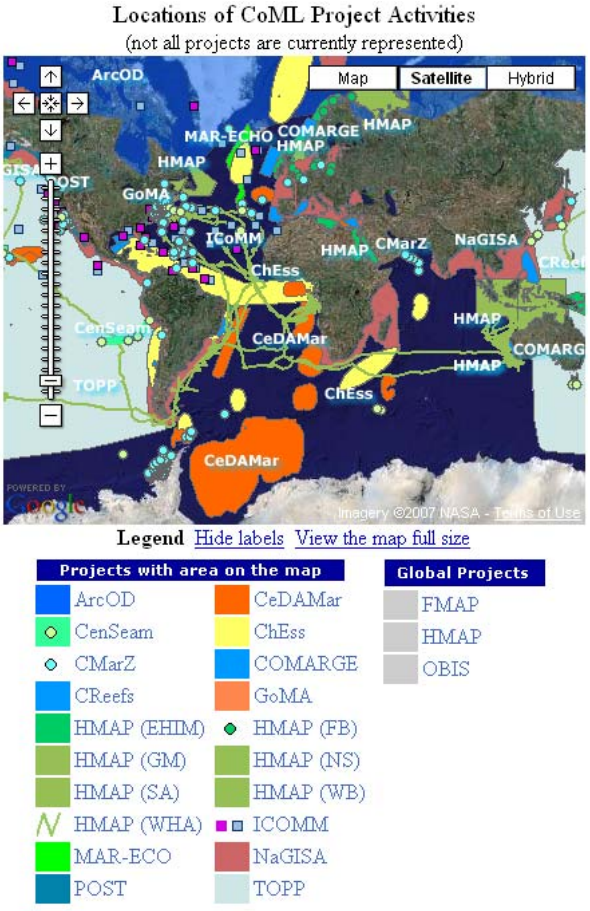


Figure 5. Interactive map of CoML activities for portal website.

Currently, the editing and advanced visualization is available through Google Earth desktop application. The interactive map on the CoML portal is rendered by Google

Maps, which only requires a standard web browser for viewing. All spatial features represented are meta-project information, not intended in any way to replace the role of OBIS as the archive of primary biogeographic observation data.

Geo-referencing Multimedia

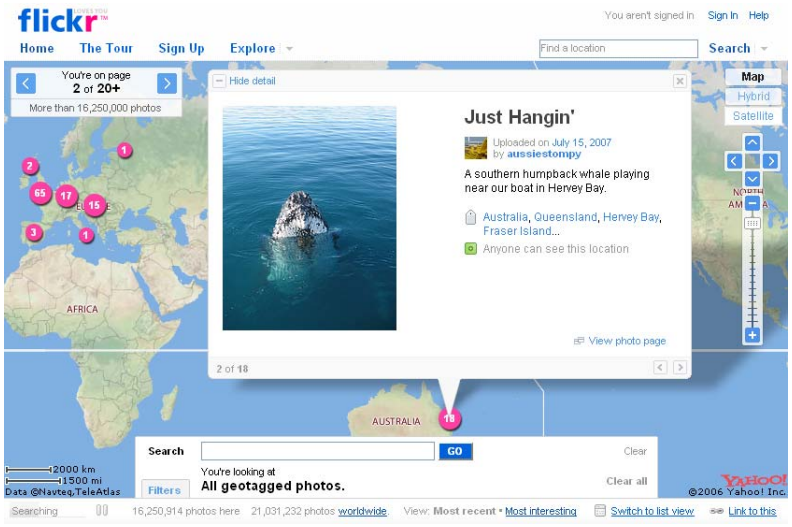


Figure 6. Screenshot of the Flickr map interface for query and display of geo-tagged photos in the Flickr collection, now more than 21 million worldwide.

Pictures and video are captured at specific locations. Increasingly that somewhere is being associated with the specific multimedia for presentation in a geographical context, i.e. "geotagging". Google Earth now displays over 1.2 million spatially referenced photos from the Panoramio community photo archive (www.panoramio.com) and countless Wikipedia entries as part of its Geographic Web layer. Photos from Flickr (www.flickr.com/map) and videos from YouTube can similarly be geotagged and mapped (Figure 7). The location information can come from metadata entered by a GPS-enabled camera at the time of recording, or entering location at the time of upload (via geocoding a place name or marking on an interactive map). The robust application programming interfaces (API) now available from the popular online multimedia services (e.g. Flickr, YouTube, Picasa, Twango, Zoomr, etc.) enable embedding of individual entries or whole galleries within individual web sites. These services vastly reduce the technical requirements (i.e. server storage and multimedia rendering) for these web

sites, while enabling aggregation and sharing. We would like to explore using these types of sharing technologies to host an aggregate Census gallery of geo-referenced imagery and scientific visualizations.

We understand existing concerns for using such services, such as issues of copyright, context and quality highlighted in the Education and Outreach (E&O) Team proposal. We will work with the E&O Team and other Census members to facilitate mapping and sharing of multimedia content for individual projects and the main CoML portal while addressing these concerns.

Project-level Support

Surveys, Workshops and Consultation

Since the fundamental mission of the M&V Team is to support mapping and visualization activities across the Census of Marine Life, we will interact with individual projects and teams through a combination of surveys, workshops and direct consultation.

The initial survey of user needs (see “A Common Technical Guide” above) will be circulated in October 2007. At the November 2007 Census E&O workshop and All-Program Meeting in New Zealand, the preliminary survey results will be reviewed and the M&V Team website and mission announced. A Spring 2008 Census mapping and visualization workshop will also be announced to take place at Duke University. This workshop will feature external experts and internal Census specialists for training, inspiring and discussing techniques with invited representatives across the Census projects. Resources gathered to date on the M&V Team website members will be

reviewed and feedback for future development will be gathered.

A second workshop is tentatively planned to be conducted in Long Beach, CA early 2009 to coincide with the “Joint Assembly” to ensure visual consistency of the 2010 final reports. This workshop will provide training in the use of templates and common visual elements, especially those cartographic in nature. We will also use this workshop to refine products from our Visualization Experiments (see below).

Individual Census projects will have direct access to the M&V Team through a host of online communication technologies, such as online text chat, audio/video conference (i.e. Skype). We can also use desktop sharing technologies to remotely guide individuals through application usage.

Census Mapping and Visualization Website

We hope to make the Census Mapping and Visualization website (proposed name: www.comlmapvis.org) a common reference for Census projects and teams. It will host documentation, tools, web services and a gallery. Users will be able to login and upload imagery or data for exchange with the M&V Team or to share within the Census or publicly. All content on the website will be based on the Plone content management system (www.plone.org), allowing any Census member to contribute useful information to the site. Workflows will stage publication so that content can be reviewed first by editors before being publicly viewable.

Spatial Gallery

As mentioned already in the section “Geo-referencing Multimedia”, we will be working

with the CoML E&O Team and other Census members to georeference image and video resources using existing online multimedia services (e.g. Flickr, YouTube, etc.) for distributed sharing. An allied component of this effort will be the development of a gallery to host pictures, video and activities data for spatial referencing in addition to scientific visualizations, such as conceptual diagrams or statistical summaries. We intend to borrow concepts from existing excellent example galleries such as those for geospatial products (e.g. http://geographynetwork.com), statistical charts (e.g. http://addictedtor.free.fr/graphiques), network visualizations (e.g. http://www.visualcomplexity.com/vc), imagery (e.g. http://www.seaturtle.org/cgi-bin/imagelib/index.pl), and symbol libraries (e.g. http://ian.umces.edu/symbols).

Tools

The tools section (similar in look to http://plone.org/products) will summarize recommended software packages and scripts, either crafted internally or linked to the external website. We will host additional services for internal tool development, such as a code repository and bug tracking, which will enable Census-specific scripts and applications to be jointly developed. Links to relevant applications (e.g. on Matlab, R, ArcGIS, Google Earth) and scripts (e.g. on SourceForge, ArcScripts, MatlabCentral, CRAN, CPAN, and Python Cheeseshop) will also be provided. This content will be tagged and categorized for querying and categorical viewing. These tools may be desktop application oriented or web-based (e.g. Google Maps, MapServer, GeoServer, OpenLayers, ESRI ArcIMS, or ESRI ArcGIS Server).

Templates for common productivity software (e.g. Microsoft PowerPoint, Word and

Excel) will be provided as well as mapping (e.g. ESRI ArcMap) and scientific visualization (e.g. Matlab, and R). Cartographic elements (e.g. color bars, scale bars, north arrows, legend fonts and symbols) can also be downloaded.

Documentation

The documentation section (similar in look to http://plone.org/documentation) will feature FAQs, How-Tos, Tutorials, Manuals, Error References, Links and a Glossary. We intend to also Flash-based tutorials guiding CoML members through common mapping and visualization tasks. Pointers to existing documentation will be highlighted. We will also be sharing useful information from authoritative texts on the subjects of information visualization (Tufte 1990, 1997, Card et al. 1999, Tufte 2001, Ware 2004, Few 2006, Tufte 2006, Spence 2007), cartography (MacEachren 2004, Krygier and Wood 2005, Andrienko and Andrienko 2006) and web authoring (Freeman and Freeman 2006). Many pointers to tasks-specific use of metadata standards, keyword vocabularies, and web services will also be provided.

Additional Services

Additional sections of the website will describe mapping and web services available (see below), as well as the various forms of communication. We will develop email list-servers for distributing updates such as newsletters summarizing additional items to the gallery, tools and documentation sections. Quick and easy online polls will get feedback on desired functionality, providing a roadmap for M&V Team development.

Interactive Mapper

One of the main M&V Team goals is to provide the capacity for every Census of Marine

Life project site to have its own interactive mapper. We have already developed prototypes for this for the main Census portal (see above Mapping CoML Activities through Time and Space). The same data can be customized with more specific information and symbology for individual projects, using the same guidelines and Google Maps technology. The process developed thus far imposes very few technical requirements on the hosting web site, making it quite feasible. We intend to offer training and guides for the Spring 2008 workshop.

Web Services for Static and Dynamic Oceanographic Data

For both visualization and analysis, we will serve base-map and dynamic oceanography data layers via geospatial web services. We intend to do this with a variety of protocols (e.g. OGC WMS/WFS/WCS, OPeNDAP, FTP/HTTP, SOAP/WSDL, ArcGIS Server) in order to accommodate the broad range of potential client programs. The M&V Team has already amassed over 4 terabytes of data for static data such as bathymetry and coastlines as well as dynamic satellite data for sea-surface temperature, chlorophyll, height and wind.

Exploratory Visualization Initiatives

In an effort to promote cutting-edge visualization for stimulating new insights and expanding perspectives across the Census, we will be exploring visualization experiments based on three themes: Realms to Globe, Network Linkages and Exploratory Data Analysis. These three areas are outlined in Appendix 3.

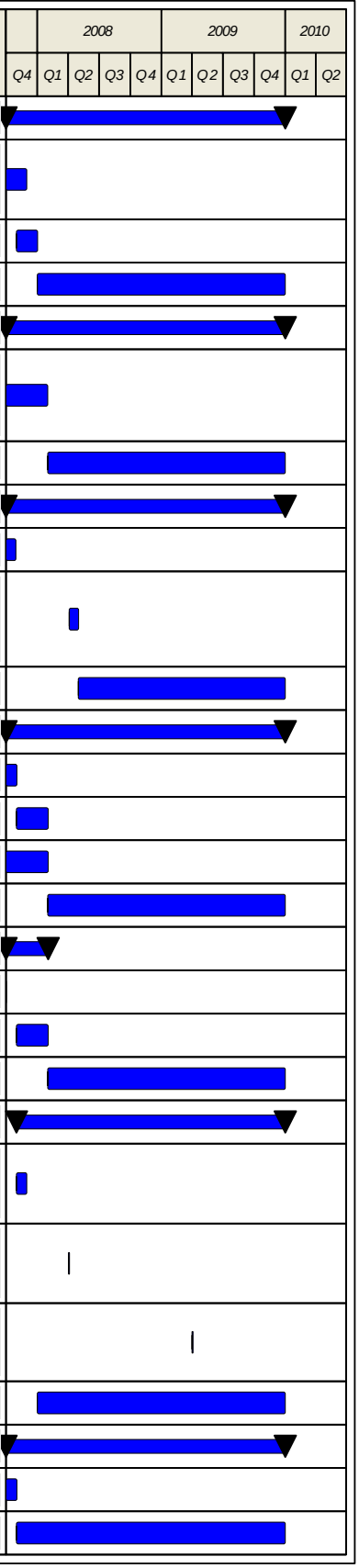
Milestones and Outcomes

Our proposal is based on three important activities (1) develop a common mapping and

visualization guide; (2) train with technical workshops and consultation efforts and (3) partner with leading institutions to promote development and dissemination of Census mapping and visualization products. We propose to act as a central technical liaison with emerging mapping and visualization partners such as the National Geographic Society, Google Oceans, and ESRI as well as other mapping and visualization specialist organizations. The Mapping and Visualization Team is expecting to develop a range of tangible products and outcomes that will be directly measurable in effect and timeliness as we achieve the larger goals stated above. Below is an outline of specific project milestones to help guide the management and external oversight of this project.

The milestones are clustered into groups of related tasks including website development, training workshops, synthesis efforts, project-level support, reporting, and coordination with partners. These milestones provide representative benchmarks of project activities and will help guide prioritization of our efforts. In addition to goal oriented milestones, the Mapping and Visualization team will set timelines for internal project management to assure that we develop the capacity and resources to meet demands of this project on schedule. Due to the short start-up time for technical development and the fixed deadline for the rollout of the First Census of Marine Life in 2010, we will be especially sensitive to our need to adhere to milestones and timelines for this project.

ID	Task Name	Start	Finish
1	**Develop website**	**10/1/2007**	**12/31/2009**
2	Initialize dedicated M&V web site (www.comlmapvis.org) using Plone content management system	10/1/2007	11/30/2007
3	Create online survey	11/1/2007	1/1/2008
4	Continued website development	1/1/2008	12/31/2009
5	**Project-level Support**	**10/1/2007**	**12/31/2009**
6	Begin work on selected high priority projects identified during the Spring 2008 technical workshop	10/1/2007	1/31/2008
7	Continued project-level support	2/1/2008	12/31/2009
8	**Reporting**	**10/1/2007**	**12/31/2009**
9	Report on initial survey results	10/1/2007	10/29/2007
10	Develop a Mapping & Visualization action plan derived from the outcomes from Spring 2008 workshop	4/4/2008	5/1/2008
11	Continued reporting	5/1/2008	12/31/2009
12	**M&V Team Management**	**10/1/2007**	**12/31/2009**
13	Initiate M&V Team	10/1/2007	11/1/2007
14	Hire additional mapping & visualization expert	11/1/2007	2/1/2008
15	Select M&V specialists within CoML	10/1/2007	2/1/2008
16	Continued M&V Team management	2/1/2008	12/31/2009
17	**Coordinate with Partners**	**10/1/2007**	**2/1/2008**
18	Google Earth	10/1/2007	10/1/2007
19	NGS draft partner plan with CoML SSC and E&O Team	11/1/2007	2/1/2008
20	Continued coordination with partners	2/1/2008	12/31/2009
21	**Host Training Workshops**	**11/1/2007**	**12/31/2009**
22	Fall 2007 All Programs Meeting: advertise the mission and process of the M&V effort	11/1/2007	11/30/2007
23	Spring 2008 Workshop: needs assessment, internet mapper training, intro to support services	4/2/2008	4/4/2008
24	Fall 2009 Workshop: templates, advanced mapping and visualization techniques	4/1/2009	4/3/2009
25	Other training	1/1/2008	12/31/2009
26	**Census-wide Synthesis**	**10/1/2007**	**12/31/2009**
27	Gather project activities geo-data	10/1/2007	11/1/2007
28	Continued Census-wide synthesis	11/1/2007	12/31/2009



Appendix 1: Project Management

The Mapping and Visualization team will be lead by the Marine Geospatial Ecology Lab at Duke University. This group has a long-standing record for innovation in the area of geospatial analysis, geographic information systems and ecological synthesis. The MGEL lab is the home of the OBIS-SEAMAP project as well as numerous other ongoing research efforts. The Principal Investigator, ***Patrick Halpin*** has been a member of the faculty at Duke University for more than twelve years and supervises laboratories at both the main campus in Durham, NC as well as the Duke Marine Lab in Beaufort, NC. In addition to a Ph.D. in Environmental Sciences, Prof. Halpin also holds a masters degree in international management. Halpin will serve as the lead project contact with the Census SSC Synthesis teams, as well as external partners.

Technical mapping and visualization research staff will include ***Ben Best***, ***Ei Fujioka*** and ***Ben Donnelly***. Each of these research staff members has exceptional technical expertise in mapping, visualization and data management as well as direct experience with the Census of Marine Life and OBIS projects and protocols. In addition to the current technical staff we plan to hire a new staff position in the field of Mapping in Visualization to provide additional dedicated effort specifically for this emerging project. The technical staff will work to develop the tools, information systems and support services outlined in this proposal as well as act as the primary technical contacts with CoML project teams.

Appendix 2: Budget

Appendix 3: Exploratory Visualization Initiatives

Realms to Globe

A promising visual interaction is the ability to toggle between the cross-sectional conceptual view of ocean realms (Figure 8) and a bird's eye view of the distribution of the selected realm, such as seamounts, over the Earth. The distribution of elements on the earth may come from CoML project activities, such as for deep-sea vents (i.e. ChESS). Or if the realm view was already chosen from a specified area, such as the Arctic (see http://www.sfos.uaf.edu/research/arcdiv/index.html), then the clickable realm elements may be taxonomically or functionally specific. These linkages could connect to mapped results from queries through primary observations from the Ocean Biogeographic Information System portal (www.iobis.org).

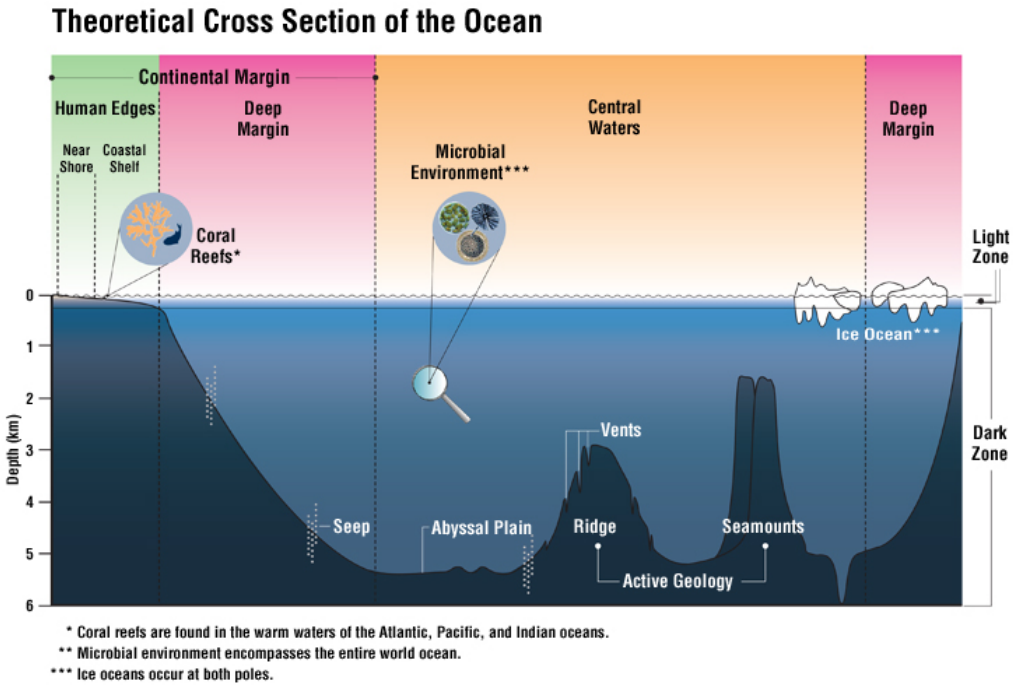


Figure 8. Ocean Realms from the Census of Marine Life Research Plan (2005).

Network Linkages

Networks are an extremely useful data structure for visualization and analysis of a myriad of biologically relevant domains (Raymond and Belbin 2006) including taxonomy (Letunic and Bork 2007), trophic ecology (Dunne et al. 2004, Estes et al. 2004, Lee et al. 2006), phylogeography (Kidd and Ritchie 2006), social networks (Bodin and Norberg 2005, Crona and Bodin 2006), and scientific workflows (Jones et al. 2006) (Figure 9).

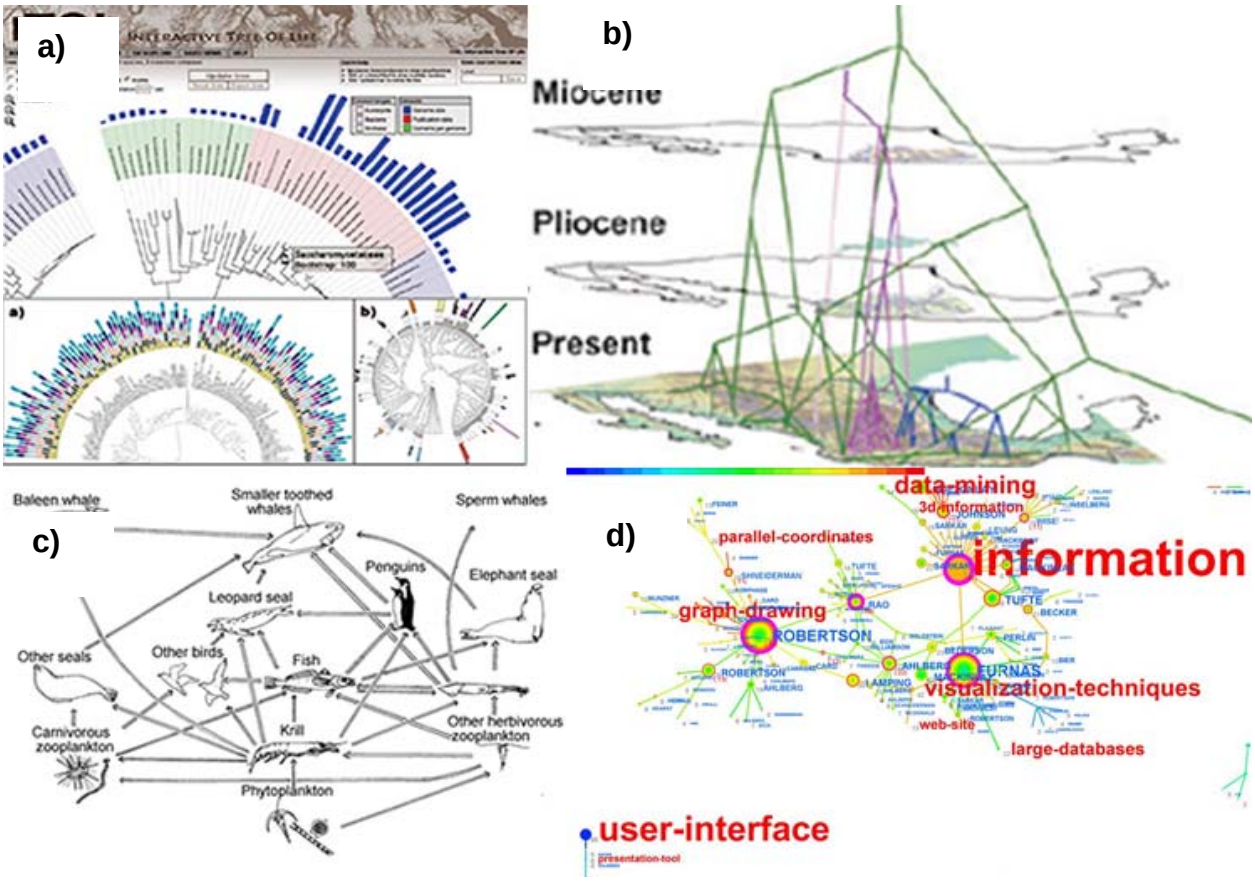


Figure 9. Network linkage scientific visualizations depicting: a) the interactive Tree of Life (Letunic and Bork 2007), b) phylogeographic relationships (Kidd and Ritchie 2006), c) Arctic food web, d) and bibliographic keyword linkages for "network."

Exploratory Data Analysis

Exploratory Data Analysis (EDA) (Tukey 1977, Andrienko and Andrienko 2006) seeks patterns in data through interactive visualization and statistical testing. Starting in Bell

Labs in the late 70's, EDA has formed the foundation of many modern statistical computing approaches, including the commercial S-Plus and open-source R statistical packages. More recently truly interactive visualizations are available within R (Lang and Swayne 2001, Adler and Nenadic 2003), and for spatial applications (Anselin et al. 2006, Bivand 2006) (Figure 10). We hope to expose these data mining methods more readily to Census project through some documentation and tools on the M&V website, in addition to direct consultation.

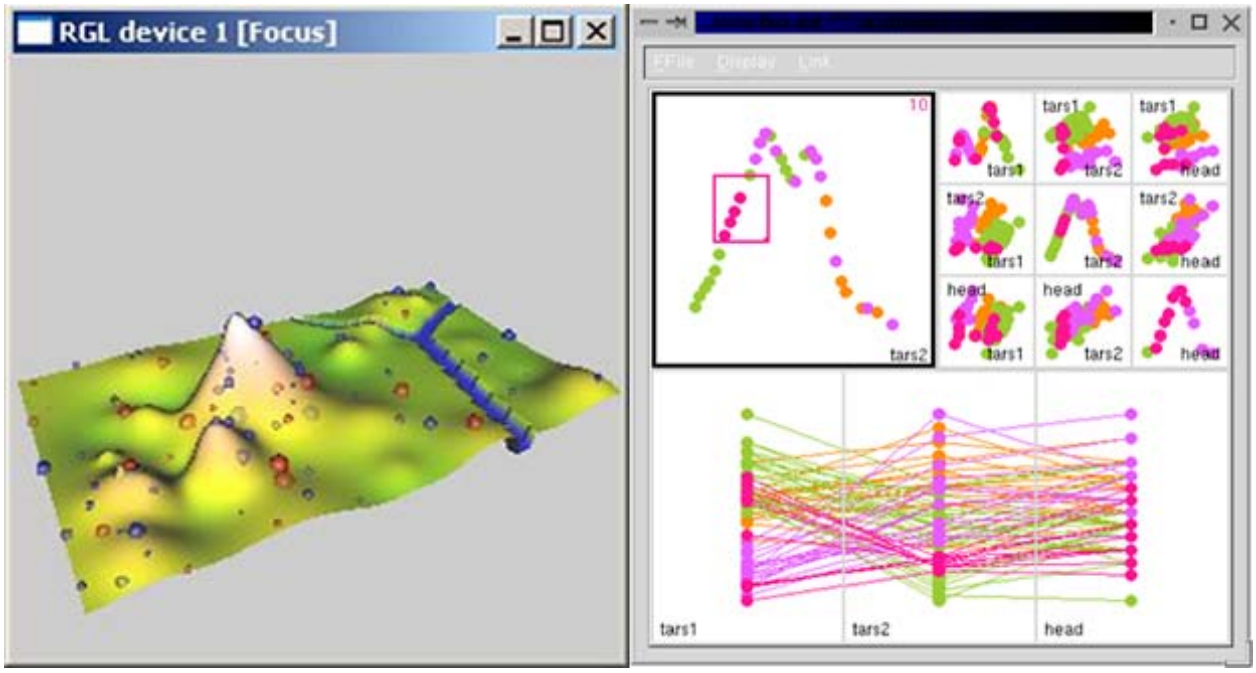


Figure 10. Exploratory data analysis using interactive visualization with packages freely available in R: a) rgl (Adler and Nenadic 2003), and b) rggobi (Lang and Swayne 2001).

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Appendix 5: PI Curricula Vitae

Patrick N. Halpin

Nicholas School of the Environment and Earth Sciences

Duke University

Durham, NC 27708-0328

Education:

Ph.D., Environmental Sciences, University of Virginia 1995;

M.P.A., International Management, George Mason University 1989;

B.A (Honors)., International Studies, George Mason University 1986;

Professional Experience:

2005 – Current: Gabel Associate Professor of the Practice of Marine Geospatial Ecology and Director of the Geospatial Analysis Program; Nicholas School of the Environment and Earth Science, Duke University

1997 - 2005: Assistant Professor of the Practice of Landscape Ecology, Nicholas School of the Environment and Earth Science, Duke University

1995 -1997: Research Assistant Professor, Nicholas School of the Environment, Duke University

1990 -1995: Research Assistant, Department of Environmental Sciences, University of Virginia;

Research Activities: Geospatial analysis and modeling of marine ecosystems, Geographic Information Systems; ecological applications of remote sensing; marine protected area management analysis, spatio-temporal modeling of benthic and pelagic habitats, marine ecosystem-based management and marine ecosystem services analysis; environmental information systems and ecoinformatics.

International Committees & Responsibilities:

Ocean Biogeographic Information Systems (OBIS): International Steering Committee

Census of Marine Life Framework Committee

US National Committee of the Census of Marine Life

Honors and Awards:

Outstanding Faculty of the Year 2007 Nicholas School, Duke University

Outstanding Faculty of the Year 2005 Nicholas School, Duke University

Outstanding Faculty of the Year 2004 Nicholas School, Duke University

Gabel Mentor of the Year 1999, Nicholas School, Duke University

Outstanding Faculty of the Year 1999 Nicholas School, Duke University

Outstanding Faculty of the Year 1997 Nicholas School, Duke University

Selected Professional Societies:

Society for Marine Mammalogy

Society for Conservation Biology

Society for Conservation GIS

American Academy of Underwater Scientists

American Fisheries Society

Recent publications in press & print:

Eckert, S. J.E. Moore; D.C. Dunn; R. Sagarminaga van Buitin ; K.L. Eckert and ***P.N. Halpin***. (in review) Hierarchical state-space models of loggerhead sea turtle (*Caretta caretta*) movement in relation to turtle size and oceanographic features in the western Mediterranean Sea. *Ecological Applications*.

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Supplement to: "*Development of the Census of Marine Life Mapping & Visualization Coordination Team"*

prepared by Patrick N. Halpin 9/16/2007

This supplement summarizes modifications to our project proposal in response to the four external reviews we received. We felt that the reviews were especially constructive and feel that the changes outlined below will directly strengthen our proposed work. We have aggregated the specific comments of the reviewers into five core thematic areas in need of improvement or clarification:

1. *Clarify how we will assess individual CoML project needs*
2. *Increase on-site interactions with CoML project teams*
3. *Specify the web-based technical and data services we will provide*
4. *More clearly define the roles of external partners*
5. *More explicitly define project coordination and oversight*

The Census project teams necessarily expect to retain ownership and creative control of the process of communicating their fundamental discoveries to the scientific and popular media. Because of this fundamental expectation, the proposed Mapping and Visualization effort is designed primarily as a ***facilitation and capacity building process***. Common tools, methods, training and direct assistance will be provided to Census project to help each project both individually and as a cohesive group communicate their findings in the scientific and popular media. The success of this process is based on active participation and buy-in from each Census team. Census-wide participation in this process began in earnest in 2006-2007 with the activities of the "CoML 2010 Framework Committee" where a participatory approach to mapping and

visualization was identified as a high priority. While developing linkages is ongoing, actively solidifying working relationships with the individual projects is the most essential initial objective of this effort. Many of the issues discussed in this supplement relate to clarifying and strengthening the necessary working relationships between the Census projects, the mapping and visualization team, the secretariat and external partners.

1. Clarify how we will assess individual CoML project needs

The mapping and visualization needs of each Census project will vary significantly based on the type of work each project is conducting, the specific mapping and visualization products they need to create and the existing technical capacity of each team. The goals of our effort are to both promote the use of a common mapping and visualization toolset across all Census projects, but also help stimulate the development of novel approaches that better represent individual project needs. Our proposal provided details on the development of common mapping tools and protocols, but did not fully emphasize how we plan to meet the unique needs of each project. In order to better meet individual project needs we will require a more individualized approach and working relationship with each Census project team. ***Working with each project team, we will develop a concise work plan outlining priority areas for technical interaction, identifying responsible project contacts, defining deliverable products and a timeline for implementation*.** These work plan documents will be used as an explicit means for setting expectations and meeting goals in a timely manner. We also plan to use this work plan format to provide an objective and transparent tool for managing our relationships with individual projects as well as providing a means for oversight by the CoML Secretariat and Synthesis Team.

We will begin developing individual work plans by engaging each project team initially with a preliminary survey scheduled to be circulated as soon as possible in October-November 2007. We then plan to use the November 2007 Census All-Programs Meeting in New Zealand to interview selected representatives from each project. We plan to follow up with project teleconferences/conference calls with the goal of developing draft work plans for each project by Spring 2008. After successful development of a draft work plan we will schedule a technical site visit to work directly with the appropriate project team members on initial design and on-site technical training (see "on-site interactions" section below). We will shift the first mapping and visualization workshop to Fall 2008 to allow for more time to (1) conduct individual project surveys; (2) develop project level work plans; and (3) conduct on-site visits prior to the first centralized meeting.

2. Increase on-site interactions with CoML project teams

Several reviewers strongly encouraged more face-to-face interactions with the individual projects to assess project-specific issues, to encourage active participation from the projects, and to promote follow-through on tasks. The M&V Team agrees that individual site visits, in which M&V experts visit with the representative project members, could have a greater impact than relying solely on centralized workshops in which only a few or one project member could attend. We agree with the reviewers and propose to reduce the number of workshops from 2 to 1 in order to use these expenses for the M&V Team to conduct a series of on-site visits before and after a single workshop Fall 2008. Initial site visits will be to develop priorities, provide on-site training, and address specific issues individual projects identify in the requisite project-specific work plan prior

to the visit. Having established a working relationship with the projects, the Fall 2008 workshop will provide training on common tools, develop break-out groups for Census-wide synthesis projects, and identify project-end deliverables. Subsequent on-site visits, again structured by work plans, will be dedicated towards final implementation and product creation geared for the Fall 2009 Joint Assembly in Long Beach, CA.

3. Specify the web-based technical and data services we will provide

The oceanographic environment directly influences the ***diversity***, ***distribution*** and ***abundance*** of marine life. The M&V team is committed to supplying the analytical tools and necessary data resources to help census projects move beyond mapping of diversity observations and into statistical analysis of potential distribution and abundance. Analysis and visualization of this dynamic environment is not only dependant on relevant tools and data repositories but also the expertise to use them. While some Census projects may be well-versed in utilizing these data sources, the hurdles in fetching, extracting, sampling and visualizing data through space and time are often a technical barrier for others. The needs assessment will establish the software packages, potential environmental covariates, and visualization needs of the projects. Armed with this information the M&V Team will be able to construct a suite of tutorials and client software tools for access to relevant online data sources. We will further provide a repository for derived products (e.g. distance to SST fronts, or eddy kinetic energy) and translated products (e.g. ArcGIS grids, Google Earth KML files) which have value specific to the marine ecology community and are not otherwise available online. Web services for access to a common set of base layers will be valuable for providing a consistent look and feel of visualized products.

4. More clearly define the roles of external partners

In coordination with the CoML Secretariat and E&O Team we will work to explicitly clarify the roles between external partners (e.g. National Geographic, Google, ESRI) with Memorandums of Understanding (MoUs) as well as explore the intellectual property options for Census content (e.g. Creative Commons, GPL). We will actively work to ensure that project results are properly attributed to the research groups and Census programs while still promoting widespread distribution across popular multimedia outlets, including through services and products offered by external partners.

5. More explicitly define project coordination and oversight

The Mapping & Visualization project plans to be an active participant in the larger CoML "Synthesis Management Team". This synthesis team is expected to closely link the CoML Secretariat, the Education & Outreach and Mapping & Visualization efforts together under a common planning and reporting framework (see draft organization diagram: Appendix 1). We are expecting that we will be in constant communications and with members of this team as well as directly reporting to the Executive Committee of the Census. Because we will be providing tangible services to individual Census projects, we expect that the most important feedback will be gained directly from these clients. We expect to work with the Synthesis Management team to develop an independent reporting system for projects to communicate feedback directly to the Chair of the Synthesis Team and Executive Committees.

Appendix 1: Proposed CoML Synthesis Management Team organization