TOWARD A MULTIDIMENSIONAL MARINE CADASTRE IN SUPPORT OF GOOD OCEAN GOVERNANCE
New Spatial Information Management Tools and their Role in Natural Resource Management

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Key words: Marine cadastre, marine governance, ocean mapping, information value, marine parcel.

ABSTRACT

The importance of the marine environment to human existence makes it imperative that information models represent the multidimensional nature of reality as closely as possible in order to facilitate good governance. Information for a jurisdiction, on the effects of its formal law and community interests on the marine environment (e.g. nature and spatial extents and the rights, responsibilities, and restrictions etc.) would be stored in a marine cadastre. Other information on the physical, biological, socio-cultural and economic nature of the environment may be linked to the cadastre to give it a multipurpose function.

This paper has the following objectives:

1. To highlight new spatial information technologies that facilitate the retrieval of various marine datasets;
2. To outline how emerging technology can be used to visualise the complexity of issues in a marine environment;
3. To outline some of the issues encountered in Canadian research in designing a marine cadastre.

1 INTRODUCTION

The United Nations Convention on Law of the Sea (UNCLOS) has provided a legal mechanism whereby a nation can extend its claims as far seaward as the limits of the continental shelf. As it explicitly deals with the rights, restrictions and responsibilities to the physical offshore, UNCLOS has created a complex multidimensional mosaic of potential private and public interests. When coastal zone management programs, and internal jurisdiction and administration issues are added on, a clear understanding of the nature and extent of offshore interests is crucial for decision-making purposes.

The importance of the marine environment to human existence makes it imperative that information models represent the multidimensional nature of reality as closely as possible to facilitate good governance. Information for a jurisdiction, on the effects of its formal law and community interests on the marine environment (e.g. nature and spatial extents and the rights, responsibilities, and restrictions etc.) would be stored in a marine cadastre. Other information on the physical, biological, socio-cultural and economic nature of the environment may be linked to the cadastre to give it a multipurpose function. Ideally, the marine cadastre would be based on a marine parcel that would be the focus of information collection, storage, analysis, retrieval and dissemination.

The first step to a complete understanding of the rights, restrictions and responsibilities in a marine parcel is integrating marine resource data (e.g. bathymetry, fisheries and oceanographic), terrestrial resource data (e.g. topographic, municipal, forestry & geological) and other land information or scientific data. This has traditionally been difficult because of varying data formats, data ownership issues, and varying geographic coordinate systems that are used. New spatial information technologies can, however, now address these difficulties.

The second step may involve a definition of a multidimensional marine cadastre parcel. A marine parcel based on the sea surface 2-D area it occupies will not usually accurately represent every legal interest that may exist in that parcel below or above the sea surface. A multidimensional definition of any given right, whether it is surface-based or not, renders a more accurate picture of the parcel. For example, the right to explore for minerals may have an impact on the seabed, but it will also affect a parcel volume that extends above and below the seabed. Policy-makers would no doubt benefit from an understanding of the upper and lower bounds of the exploration rights, and how these may affect the environment or other property entitlements within the same parcel.

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2 NEW TECHNOLOGIES FOR UNDERSTANDING MARINE ENVIRONMENTS

We now have technologies that allow us to not only see the water column (e.g., schools of fish) but also the seabed surface and the geological structure beneath the surface. Technologies for sidescan sonar, single beam echosounders, multibeam sonar and seismic surveys provide the tools for systematically exploring and describing ocean frontiers more clearly. In conjunction with sophisticated visualization software, the imagery allows users to view the living and non-living resources in the coastal and offshore areas. It is not difficult to see that these same technologies can be used to view the complexity of the associated rights, responsibilities and restrictions in the coastal and offshore areas.

Below are some of the technological advances that make the creation of a truly multi-purpose, multi-dimensional marine cadastre possible.

2.1 Sidescan and Multibeam Sonar

Until the advent of the multibeam echosounder, the lead line and the single beam echosounder were effectively the only methods of accurately determining depth to the required standards in order to meet maritime user requirements [Hughes Clarke et al., 1998, Holmes, 1999]. These older technologies implement interpolation strategies that provide “more” information from sparse information. Advances in technology have increased maritime user expectations for more information based on fact rather than assumptions.

Like the towed side scan sonar, the sideways looking multibeam can be used to collect acoustic backscatter information to produce imagery[Hughes Clarke, 1994, Hughes Clarke et al., 1998, Holmes, 1999]. The towed sidescan sonar has the advantage of achieving better angle of incidence, being naturally closer to the seafloor, however the hull mounted multibeam sonar can normally obtain a wider coverage. Coupled with the fact that multibeam has an inherent attitude sensing advantage, images can be corrected to accurately reflect the true size and shape of water column and seafloor features [Hughes Clarke, 1994, Hughes Clarke et al., 1998, Holmes, 1999].

We have gone from discrete lead line depths to obtaining 100% bottom coverage. From a cadastre perspective, this represents an important step as it allows us to visualise contents of the base map in a marine cadastre. Consequently, we now have a framework that will allow us to relate the marine parcel to natural and man-made features on the sea floor.

2.2 Visualization Software

Visualization of the complexity of rights in marine spaces is of particular importance in understanding the multidimensional context in which marine activities take place. Most marine rights, such as aquaculture, mining, fishing, and mooring rights and even navigation have an inherently multi-dimensional nature that makes a two-dimensional definition of these rights legally inadequate [Nichols et al., 2000]. Where and how do these rights overlap? It is entirely possible that any two marine rights intersect not at the surface of the water, but at some point far below, in the water column or even within the seabed. In order to control and regulate marine activity, a more accurate portrayal of rights in the “marine parcel” is required (for example Fig 1). Policy-makers would no doubt benefit from an understanding of the upper and lower bounds of the marine rights, and how these may affect the environment or other property entitlements within the same parcel (Hoogsteden and Robertson, 1998, 1999).

GIS Software that allows the visualization of the above-mentioned multiple dimensions is still in its infancy. Software such as CARIS LOTS™, Arcview™, CARIS GIS™ etc allow interaction with terrain (and marine) profiles. However, this limited perspective cannot compare to the Computer Aided Design (CAD) systems that have advanced 3D modeling capabilities. CAD systems often suffer from limited facilities for data management and operate on local coordinate systems. This means that newer 3D GIS-enabled software such as Fledermaus™, or even 3D modeler in Arcview™ , which facilitate interaction with the 3D data through flythroughs, need to be used to correctly represent the multidimensional marine cadastre.. Research at the University of New Brunswick is following up on the ability to manipulate 3D marine spatial information using Fledermaus™ for the purpose of identifying a multidimensional marine cadastral parcel.

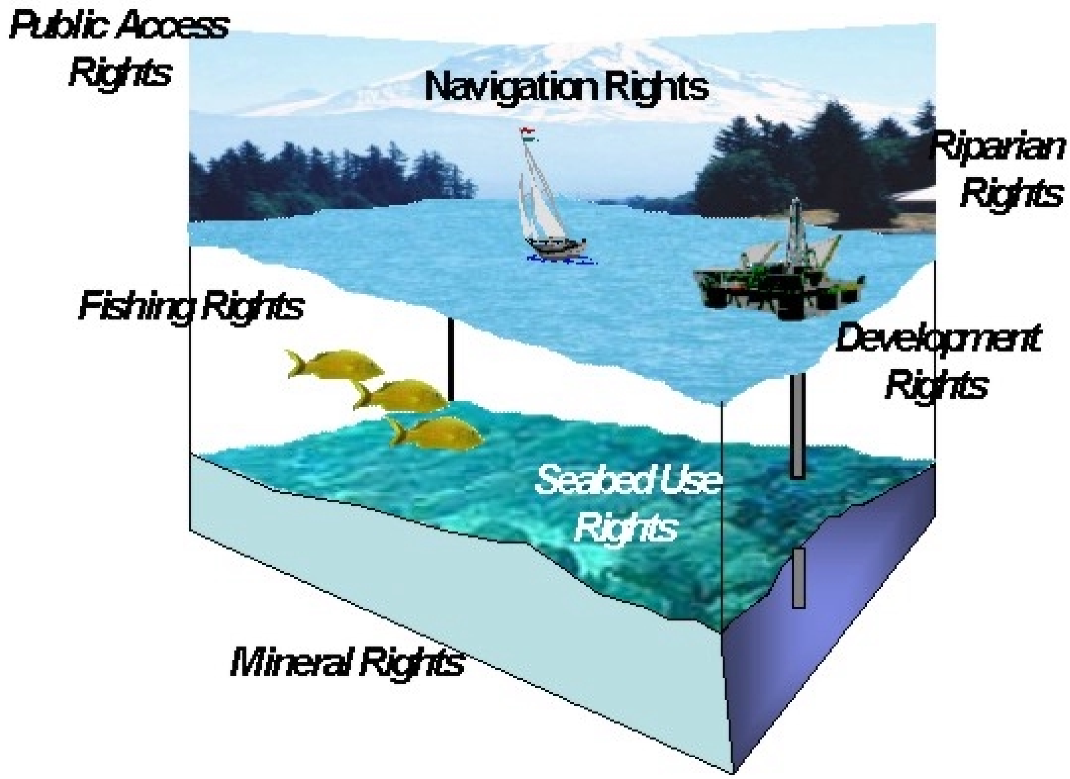

Figure 1: The Marine Parcel (after Sutherland, 2001)

2.3 Spatial Fusion Techniques

In a bid to take advantage of Internet technologies, most organisations with spatial information make their information available on the web. Map distribution and viewing applications built by these organisations deal with a relatively new paradigm, which has shifted the focus from a desktop application (fat client) to a browser-based architecture (thin client).

Webmapping solutions are now available on several Internet sites. Many of them focus on the ability to incorporate a thin client approach to information dissemination. Examples include, Universal Systems' CARIS Spatial Fusion™, Intergraph's Geomedia Webmapper™, ESRI's Arc Internet Map Server (Arc IMS™), and several others. We briefly outline CARIS Spatial Fusion™ webmapping solution currently being used at the Geodesy and Geomatics Engineering Department at the University of New Brunswick.

CARIS Spatial Fusion™ is an Internet-based technology whose primary function is accessing, visualizing, and analyzing heterogeneous, distributed data sources [Fitzgerald, 2000,Webmapper.com, 2000]. Like other webmapping solutions, Spatial Fusion™ combines the speed, convenience and simplicity of the Internet but also has the ability to read multiple data sources in their native format.

Spatial Fusion™ consists of a customized Java client and a number of Fusion Data Services. This combination is built on the ability to connect distributed data services and thin customizable clients. On the client side, a java enabled web browser is used to access, retrieve and manipulate data available on the server side. Not only does this keep the client thin, but also it secures the data itself by keeping it on the server [Fitzgerald, 2000].

These and other technologies are being leveraged to provide access to marine datasets in their native formats, at different locations, and using easily available web browsers. This provides the necessary framework for integrating marine resource data (e.g. bathymetry, fisheries and oceanographic), terrestrial resource data (e.g. topographic, municipal, forestry & geological) and other land information or scientific data, necessary for decision-making in the marine environment.

3 THE NEED FOR BETTER OCEAN GOVERNANCE

In 1996, the Land Studies Group at the University of New Brunswick was asked to examine the property rights issues related to the growing aquaculture industry in Atlantic Canada. There has been traditional aquaculture industry for over a century, largely related to lobster, oysters, and clams. In the late 1970s the Bay of Fundy (which has a tidal range of approximately 16 metres at the head of the Bay) became the focus of salmon farming. By 1997 this was a multi-million dollar industry and was heavily supported by government, especially in light of the closing of much of the traditional North Atlantic fishery.

Aquaculture on this scale was new and the need for large financing created the need for more security of tenure than was afforded by delimiting a site on an aerial photograph or hydrographic chart. In addition, salmon aquaculture raised issues such as economic impacts on local communities and coastal properties and environmental impacts in surrounding waters. The study conducted outlined the many and diverse property right and jurisdictional issues and became the seed of a larger ocean governance research project reported here. [Nichols, et al., 1997]

At the same time Canada was developing a new Oceans Act, in large part to finally address the many issues raised with extending Canadian jurisdiction offshore under UNCLOS. Canada has yet to ratify this convention but has adopted most of its provisions, as has the United States. Of special interest to Canada is the ability to claim a continental shelf zone beyond 200 nautical miles where the physical continental shelf extends beyond the Exclusive Economic Zone. The difficulty is that in Canada we have limited information has to where the physical shelf is, especially given the geological and hydrographic criteria contained in Article 76 of UNCLOS [see for example, Wells and Nichols, 1994]. To delimit this shelf area with precision would require vast data collection programs. The Canadian Hydrographic Service and the Geological Survey of Canada have thus focussed on the potential opportunities of new ocean mapping technologies such as multi-beam sonar and developing software, such as CARIS LOTS™ to create boundary choices using existing data.

A third factor affecting ocean governance in Canada is the need for better approaches to sustainable development along the Atlantic, Pacific, and Arctic coasts. Each region has its own issues; for example, in the Pacific there has been a moratorium on oil and gas development until land and resource claims made by First Nations (Canada's indigenous peoples) are settled. In the East Coast, a 1999 Supreme Court of Canada case recognized certain aboriginal rights to the Atlantic fishery. These claims are in competition with a declining traditional fishery and increasing aquaculture and petroleum development activities. [e.g., Monahan, et al., 1999, 2001]

What exactly constitutes sustainable development strategies for the Atlantic Canada, probably depends on one's professional discipline, one's economic dependence on the ocean resources, and one's vision of the oceans as a national or international resource pool. In Canada, however, the federal and provincial governments know they have to overcome problems such as the following in order to promote good ocean governance [e.g., Nichols et al., 2001]:

- The almost *ad hoc* division of powers for marine activities between levels of government and between various departments;
- The lack of complete and comprehensive data sets (much data is collected on a project basis);
- The lack of information standards including standards for the definition of a coastline which could be used as a reference for delimiting offshore boundaries;
- The emerging uncertainty surrounding aboriginal rights and other traditional rights.

4 THE CONTRIBUTION OF A PROPERTY RIGHTS INFRASTRUCTURE TO GOOD OCEAN GOVERNANCE

In Canada and most other countries of the world, plans are designed, decisions are made, and activities take place in the bordering ocean spaces without too much regard to the impact on any existing property rights. An example is the creation of Marine Protected Areas (under, for example, Canada's new *Ocean Act*). The objectives for establishing these areas include environmental and socio-economic criteria but they can potentially impact on, for example: oil and gas development rights, including cables and pipelines, traditional fishing rights, aboriginal rights, coastal property rights (including riparian rights), as well as rights for public navigation, recreation, and access. Yet the MPA administrators, NGOs and community groups involved cannot go to a single source and discover what rights might exist in a specific area. This example, and many more are the rationale for creating a more complete marine property rights cadastre in Canada. Such a cadastre would be part of the Marine Geo-Spatial Infrastructure for the country.

In June 2000, we began a research program that now has support from several federal agencies, provincial government, and the private sector and is beginning to spark interest in the international community. The objective was to examine the use, value, and significance of marine boundaries (the spatial component of the property infrastructure) in good governance of Canada's oceans. The specific objectives include: 1) developing a model for the information requirements for ocean governance [e.g., Wilkins et al, 2001]; 2) examining marine boundary uncertainty from legal, social and environmental perspectives[e.g., Cockburn et al, 2001], as well as from a geodetic perspective [e.g., Monahan et al, 2001]; and 3) extending current spatial information technologies [e.g., van de Poll, 2000].

This is a truly interdisciplinary project with researchers from 4 universities representing governance theory, law, economics, sociology, land administration, and ocean mapping. The project also has three case studies:

- a portion of Canada's extended continental shelf;
- a proposed Marine Protected Area in a coastal estuary;
- provincial marine administrative boundaries.

In all three case studies new spatial technologies have been used to collect, process, and visualize the results. Test demonstrations have already begun to raise awareness within government and community groups about what the property rights issues are; 3-D visualization software has contributed to identifying problem areas, new approaches to marine property rights, and communicating the complexity of the issues to senior levels of government as well as to community groups [e.g., Paul et al., 2001].

5 KEY ISSUES IN DEVELOPMENT OF A MARINE CADASTRE

In this section we report examples of the results of the research to date, especially as it relates to a marine cadastre.

5.1 Governance Issues

a) **Boundaries as a governance solution or a governance problem?** As surveyors we approached the governance issue from the perspective that "good boundaries make good neighbours" and that clarity of boundaries would improve governance. The legal specialist on the other hand argued that the law only eliminates ambiguities when an issue occurs, i.e., boundary delimitation should be dispute-driven. The social scientists added another dimension and emphasized the need to not draw boundaries in ocean spaces where co-management of resources may be a better solution.

b) **Multi-organizational and multi-disciplinary approaches required:** There are many stakeholders and a main function of governance is to improve the communication and collaboration among them. New models need to be designed for ensuring that planning and decision-making processes are inclusive. This is a radical shift from the department-mandate-driven and single-discipline-oriented approaches that are traditional in government and in research.

5.2 Legal Issues

a) **Better understanding the distinctions in law between jurisdiction, administration, and ownership:** In non-legal discussions, the distinctions tend to be blurred. However, in the oceans the distinction is critical to understanding the complexity of government authorities with respect to control, ownership, and use of marine spaces and specific resources. There is a need to ensure exactly what kinds of rights and restrictions are being reflected in the cadastre. In Canada, for example, we began by thinking of single administrative boundaries for the provinces. As the research evolved we realize it is necessary to try to represent multiple administrative boundaries in the cadastre for various resources, areas, and uses.

b) **Definition of a multi-dimensional "marine parcel":** The multipurpose cadastre concept has been traditionally designed on a three dimensional spatial unit representing unique, homogeneous, contiguous interests [see McLaughlin, 1975; NRC, 1980; Moyer and Fisher, 1978]. In some senses the cadastre also represented a fourth dimension, time (e.g., time-shared interests). In the oceans where resources and activities, and therefore rights and restrictions, can co-exist in time and space and can move over time and space, the definition of a parcel is even more complex. Furthermore, it may not be the best unit of representation for all interests (such as the overlapping administrative units described above). Until another framework is proven more useful, the cadastral concept may help the initial exploration of ideas. However, it may be more useful in the long term to look at broader contexts such as property rights infrastructure, MGDI, and environmental or ecological units in order to ensure that we are not asking the resources and their management to follow our sometimes arbitrarily straight surveyed lines in space.

5.3 Spatial Information Issues

a) **Need for Information Standards:** While a broad range of standards is required to improve the accessibility and use of marine data, the need for a coastline standard is essential to merging land, coastal, and marine data sets. Perhaps nowhere in the world is this more apparent than in the Bay of Fundy, which is said to have the greatest range between high and low water in the world and where many parts of the coastline are tidal flats. The difference between high and low water mark can be as much as 300 or 400 metres. The discrepancies may be significant when merging data sets that variously refer to "ordinary high water", "lowest low water astronomic tide", "mean water level", or no datum at all. Accentuating the problem is the fact that most mapped shorelines are not tide level-controlled, but an approximation from aerial photography or other surveys many years ago.

b) **Recognizing the Limitations of Technology**: A marine cadastre is not a technology solution. In fact the technology, although enabling us to visualize some of the issues more clearly, may inhibit our understanding as well. There are issues such as: a) loss of information through generalization; b) assumptions that a set of data must be accurate or complete because it is in digital format; c) a tendency to be overwhelmed by the colourful images rather than paying attention to the actual problem. What we need to do is use the technologies more wisely to better communicate the information we have (and its limitations) to a broader range of people.

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