Developing Marine SDI to Facilitate Marine Administration-the Spatial Dimension

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ABSTRACT

The coastal zone is a unique geologic, ecological and biological domain of vital importance to a vast array of terrestrial and aquatic life forms-including humankind. Managing the plethora of rights, restrictions and responsibilities of resources within the marine environment and at the littoral zone has created one of the world’s most complex areas of management. Evidently effective administration and management of these areas to meet the economic, social and environmental objectives of sustainable development is required.

Until recently spatial information management and administration tools have focussed on the terrestrial environment. Initiatives such as the 3rd United Nations Convention on the Law of the Sea (UNCLOS) and the Sustainable Development Strategy for the Seas of East Asia (SDS-SEA) have brought to attention the importance of sustainable development of the coastal and marine environment. The concepts of marine spatial data infrastructure (SDI), marine cadastre and marine spatial planning have all emerged recently in response to a global realisation of the need to improve management and administration of the marine environment. The underlying theme of these initiatives is the importance of including a spatial dimension to marine administration. A more integrated and holistic approach to management of coastal and marine environments would be facilitated by the extension of the SDI on a seamless platform. This would promote data sharing and harmonisation between large numbers of diverse data holdings and an increasingly large number of initiatives in marine data thus facilitating better decision-making involving marine and coastal spatial information.

A seamless SDI platform would enable the utilisation of common boundaries across the coastal zone to ensure no ambiguity exists and no areas are unaccounted for over the coastal interface. This paper discusses the potential for adding a marine dimension to an SDI in the context of seamless model to facilitate marine and coastal zone administration and highlights the need for access to and interoperability of data from marine, coastal and terrestrial environments resulting to the better and more integrated management of coastal zone. Ideally this framework would harmonise the stewardship of and access to marine data and information, thereby facilitating improved management of marine environment.
INTRODUCTION

Humankind is extremely reliant on the world’s coasts and oceans, as a source of food and wealth, as a climate regulator, for transportation, shipping, waste disposal and recreation. There are serious environmental issues such as the threat of sea level rise and natural resource depletion, which need to be balanced with economic development and social concerns. Many countries are reliant on marine industries such as oil and gas exploration, fishing, aquaculture and tourism. Often there is a social attachment to the coastal zone, with many people choosing to holiday and live close to the beach and native title interests in many countries over these areas. As the use and understanding of the marine and coastal environment has increased, so has the need for improvement in the management and administration systems for these areas. This idea is reflected in the number of initiatives worldwide that aim to improve marine and coastal management such as the Sustainable Development Strategy for the Seas of East Asia (SDS-SEA), Integrated Coastal Zone Management (ICZM) and the 3rd United Nations Convention on the Law of the Sea (UNCLOS).

Worldwide countries are realising the need to balance development and exploitation of resources in the coastal zone with environmental and social needs. In the terrestrial domain, the need to share and integrate spatial data for more efficient resource information management has been recognised for over a decade, and has led to the development of Spatial Data Infrastructures (SDI) at all geographical levels from the purely local to the national and global[1]. SDI creates an environment that will enable users to access and retrieve complete and consistent spatial datasets in an easy and secure way. Until recently the SDI concept has largely overlooked the marine and coastal environments, focussing mainly on connecting people with land-related data and information. However the marine and coastal environments play an important role in many areas of human life and thus the ability to access and share accurate and up-to date spatial information about these areas is also important. The concepts of marine SDI, marine cadastre and marine spatial planning have all emerged recently in response to a global realisation of the need to improve management and administration of the marine environment. However there is still the need for an overarching spatial information platform to facilitate the use and administration of these tools in a holistic fashion.

The complex physical and institutional relationships existing within the coastal zone make it impossible for development of a marine SDI to occur in isolation from land based initiatives [2, 3]. There is a growing need to create a seamless SDI model that bridges the gap between the terrestrial and marine environments, creating a spatially enabled land-marine interface to more effectively meet sustainable development objectives. This would promote data sharing and communication between organisations, thus facilitating better decision-making involving marine and coastal spatial data. However, the differences in the marine and terrestrial environments in terms of fundamental datasets, data collection and technology used in these environments will make interoperability and integratability between marine and terrestrial spatial data a challenge. Research
now needs to focus on combining these initiatives and developing a seamless platform to be able to model, monitor and manage both marine and land environments particularly the land-sea interface. This was recognised in 2002 by ANZLIC, Australia’s peak spatial information council, which extended the definition of the ASDI to also include the marine environment, however most current SDI models stop at the coastline both spatially and institutionally. The reality is that the need for access and coordination of spatial data does not stop at the coastline.

With this in mind, this paper discusses marine management issues and challenges and the potential for adding a marine dimension to an SDI to facilitate marine and coastal zone management. It looks at global drivers for improvement of marine and coastal administration. Further it discusses the need to develop a seamless SDI as an enabling platform to increase the efficiency and effectiveness of management across regions and disciplines followed by an introduction to issues and challenges that must be overcome in developing an overarching architecture for a seamless SDI.

MARINE MANAGEMENT ISSUES AND CHALLENGES

As the interface between the land and marine, the coast is a unique geologic, ecological and biological domain of vital importance to a vast array of terrestrial and aquatic life forms—including humankind. The importance and value of the coastal zone can not be underestimated. Since early settlement days the coastline has been used in a number of ways. Largely for transportation reasons, major industrial and commercial centres developed around port cities. Indeed, some two-thirds of the planet’s population lives in a narrow 400-kilometer coastal band. Demographic trends suggest that coastal areas around the world are undergoing serious population growth pressures. Population growth is the driver behind many, if not most, coastal problems [4]. The population and development pressures that coastal areas experience generate a number of critical problems and policy issues and raise serious and difficult challenges for coastal planners. Population density is another measure of the stresses placed on coastal areas; when more people are using a limited resource, the carrying capacity of the region can sometimes be exceeded. Protecting the coastal environment while accommodating such growth pressures will be a major challenge.

The coastal environment is one of constant change, with many natural pressures such as wind, waves, currents, tides, etc. creating a change in topology. However, it is the effect of human induced pressures that can be far reaching and long lasting. Human activity can interfere with the natural processes of the coast and prevent the ecosystem from maintaining the equilibrium so necessary to its continued vitality. Human pressure exerted on the coastal region also involves the disposal of waste. Society is now using resources and producing wastes at rates that are not sustainable. Oceans and the coastal zone have been used as dumping grounds for many years. For instance population increases along Australia’s shorelines and the corresponding industrial development has resulted in a rapid increase in sewage outflow into rivers, estuaries and oceans
It is important to consider that land-based sources of marine pollution are around 80% of contamination in the marine environment [6].

The coastal zone is also one of the most productive areas accessible to people. There are increasingly serious signs that economic uses of our coast are undermining their long term sustainability. Over fishing is exhausting and deleting fisheries around the world. As an example in Australia, according to the Bureau of Rural Sciences [7] 11 target species in Commonwealth fisheries were classified as over fished, 11 as fully fished and a further 35 classified as ‘uncertain’, despite the highly regulated and generally regarded best-managed fisheries in the world. This over fishing came about partly due to lack of knowledge of the distribution, abundance and biology of the stocks, but also due to inadequate management arrangements resulting in unsustainable catches [8]. Additionally in recent decades production of offshore oil and gas has generally been declining due to the resource becoming depleted. Other major issues and challenges which coastal stakeholders are struggling with are:

- coastal storm mitigation
- loss of biodiversity habitat and coastal wetlands
- shore line erosion and sea level rise
- climate change
- lack of suitable sites for aquaculture
- private property versus the public interest in coastal planning
- protecting marine heritage and
- marine defense

These issues and their potential impacts are forcing coastal states and localities to resolve how best to cope with. Figure 1 illustrates current marine and coastal issues and challenges.
GLOBAL DRIVERS FOR IMPROVEMENT

In the past two decades there has been increased focus on the marine and coastal environments and improving management and use of these areas. There are several initiatives that aim for sustainable development of the coasts and oceans. Sustainable development is driving the need for better marine and coastal zone management and administration. The Sustainable Development Strategy for the Seas of East Asia (SDS-SEA) is one of those initiatives which aims to implement the World Summit of Sustainable Development (WSSD) requirements for coasts and oceans in East-Asia. SDS-SEA sets out a policy to ‘sustain, preserve, protect, develop, implement and communicate ’aiming to balance the social and economic reliance of East-Asia on the marine and coastal environment, with the need to preserve and protect these ecosystems. This policy also highlights the conflict arising from developing separate ‘property rights regimes on both sides of the coastal zone’ [9], understanding the need for a holistic approach on and off shore. SDS-SEA recommends improving dissemination of reliable and relevant data, and encouraging organisations to share data. The organising body Partnerships in Environmental Management in the Seas of East Asia (PEMSEA) is developing an ‘integrated information management system (IIMS)’ to address this recommendation.

Multiple reports internationally have highlighted the need for better coordination and integration between and within levels of government to improve coastal zone management [10, 11]. In this respect, Coastal Zone Management (CZM) initiatives are turning to more integrated strategies worldwide, attempting to harmonise economic, social and environmental objectives, similar to the better-
developed land use management frameworks of many urban areas. In coastal areas however, the diversity of interests, some terrestrial and some marine, compounds the issue. Integrated coastal zone management (ICZM) is an initiative which has become the standard approach to coastal planning and management [12] with nearly 700 ICZM initiatives occurring at international, national and sub-national levels [13]. ICZM recognises the need to integrate planning and management over the land-sea interface and so there is a need for data and information that covers both these areas [14].

A common theme from many of the initiatives that aim to improve coastal and oceans management is the desire for access to appropriate and reliable spatial information to support these initiatives. Spatial information aids decision making by providing a spatial/geographic context to planning, management and resource allocation and is increasingly recognised as essential to emergency response. It enables a better understanding of an area and thus better management [15]. Many coastal management issues could be overcome if a spatial data platform that enables a holistic, integrated and coordinated approach to spatial information for decision-making existed. SDI provides an enabling platform enhancing decision-making and facilitating a holistic approach to management. To improve management of the coastal zone there needs to be access and interoperability of both marine and terrestrial spatial data [16].

The data requirements of coastal zone managers go beyond those of their more-terrestrially-focussed counterparts, in scale, geographical extent and complexity of definition, leading to the need for specifically coastal-oriented SDI research and implementation [17]. However the need to effectively manage the coastal zone as well as the need for interoperable data between the three environments (land, coast, marine) requires a management system that incorporates them all.

SEAMLESS SDI

Currently there is a lack of coordination and sharing of marine spatial data mainly due to a lack of standards for sharing data, different data formats, little to no recording of metadata, different reference systems used, lack of willingness to share data, difficulty is finding data and gaps in data availability [18]. These issues have been recognised as a barrier to effective marine management in many countries and in response in Canada, Ireland, USA, New Zealand and Australia and at regional and global levels, the concept of a Marine SDI is emerging [1]. While the initiatives within each country have different names and are at a different stage of achievement, they all have very similar aims – to improve marine and coastal zone administration and management through better availability and applicability of spatial data. Although many countries are now addressing this problem, often the Marine SDI is developing as a separate initiative to the terrestrial one. The uniqueness of the marine environment means that the existing terrestrial system may not be appropriate for use in these areas. In a land based environment, there is a land administration system that is supported by an SDI, as a facilitating framework and a cadastre, as one of the important layers. There are ideas and drivers to support the development of a
marine administration system and it is usually recognised that this must also be supported by an enabling platform such as an SDI.

A more integrated and holistic approach to management of coastal and marine environments would be facilitated by the extension of the current SDI model to include land and marine environments on a seamless platform. This would promote data sharing and communication between organisations thus facilitating better decision-making involving marine and coastal spatial information.

Both the marine and terrestrial environments are tightly integrated systems in which all the parts are interrelated and dependent on one another. Destruction or degradation of one component can lead to impairment of other parts or the dysfunction of ecosystem as a whole. If two separate SDIs were created it would deepen the gap between these two administration systems and make coastal zone management more difficult. There is an opportunity for more research to be conducted into combining these initiatives and developing a seamless SDI that can include spatial data from all environments. This will recognise the interrelatedness of the marine and terrestrial environments and also improve management of activities or resources that occur across these boundaries [1].

A seamless infrastructure aids in ‘facilitating more integrated and effective approaches to coastal zone management, dealing with problems such as marine pollution from land based sources’ [19]. A seamless infrastructure was endorsed by the UN as part of the International Workshop on Administering the Marine Environment held in Kuala Lumpur, Malaysia, 2004 [20]. It was recommended that a marine cadastre act as a management tool within a marine SDI as an extension to NSDI’s across Asia-Pacific. Recently, a recommendation of the 17th United Nations Regional Cartographic Conference for Asia and the Pacific (UNRCC-AP) in Bangkok further supported the inclusion and development of a marine administration component as part of a seamless SDI to “ensure a continuum across the coastal zone” [21].

A seamless SDI can be seen to have the following characteristics:

• Seamless, the digital spatial data is stored continuously throughout and across any jurisdictions
• Multi-purpose, the same data can be used for different purposes.
• Multi-users, the same data can be accessed by different users concurrently.
• Interoperable, the data stored in the database can be accessed using different GIS software and applications.

The sharing and integration of coastal databases across regions and disciplines through SDI development would permit harmonised and universal access to datasets from land-based, coastal and marine spatial data providers so that complex issues affecting the coastal zone can be properly and efficiently addressed in many economic, environmental and policy areas [17]. A seamless SDI platform would enable the utilisation of common boundaries across the coastal zone to ensure no ambiguity exists and no areas are unaccounted for over the coastal interface. This infrastructure will become a powerful information
resource for managers in fields as varied as fisheries habitat management, pollution monitoring and control, shoreline erosion, weather forecasting and tourism development, etc. The information that can be derived from such a fully integrated information infrastructure will facilitate improved decision making at all levels. However for creation a seamless SDI, a number of technical, institutional and policy issues would need to be overcome in order to facilitate the management of the land sea interface.

**ISSUES IN DEVELOPING A SEAMLESS SDI ARCHITECTURE**

In order to create a seamless SDI across land and marine environments and jurisdictions, it is important to recognise and accept that building and maintaining an SDI is not an easy task even for well-developed states. It is a dynamic and complex process at different levels of government and requires research and collaboration with academia and private industry. Issues and challenges in developing seamless SDI can be divided into three different categories which are technical, institutional, and legal and policy issues.

**Technical Issues**

It is often difficult to find coastal geospatial data and/or derived products. Once located, it is often difficult to judge the quality of the data or to understand the limitations that apply to their use. With differences in scales, datums, projections, formats, or resolution, the data are often difficult to handle and even more difficult to integrate. From a technical point of view, the lack of spatial data standards that are implemented at a national level is the main problem of the above differences. Each institution or organization creates spatial data for their own purposes using their own technical specification without considering that the data may be shared or distributed to larger communities. The implementation of spatial standards at a national level will assure that every institution and organization creates spatial data in the same manner and it will ease spatial data sharing and exchange. These must be developed using the international procedures and practices in order to cover not only the national needs but also cooperation at an international level.

Another concern linked to the establishment of seamless SDI is the issue of a national shoreline. As the fundamental boundary for so many applications and studies, the lack of a consistently defined shoreline has frustrated coastal zone managers, planners, and scientists for many years. Therefore different representations of the coastline in marine and land datasets leads to data overlaps while most of the application requires a single seamless layer of information with no duplication of common features. A single nationally accepted and consistent shoreline should be defined. The consistent definition of the shoreline would thus not only reduce legal and jurisdictional confusion but also would undoubtedly lead to increased data acquisition efficiency.
Institutional Issues

The coastal zone is difficult to manage due to the fact that it is governed by a complex array of legislative and institutional arrangements from local to global scales. A coastal state may be a party to many international conventions (i.e. RAMSAR, MARPOL, and London Convention) in addition to developing its own national, and even state or local regulations. Activities and resources are usually managed in a sectoral and ad-hoc approach with legislations or policies created when the need arises and specific to only one area of interest [16]. Furthermore, there is currently some confusion about the management of the land-sea interface, an example being in Australia where local governments manage land to High Water Mark (HWM), and state governments manage the marine environment from the Low Water Mark (LWM). This means that there are no overlapping arrangements in place to enable efficient coastal zone management. There is also a strip of land between the two boundaries which is not within a management jurisdiction at all [22].

In any jurisdictions groups typically collect and maintain data to support their own specific disciplines or programs, with little or no consideration given to collecting, processing or managing data for use by other users. As such, available data are often inadequate for clear, rational decision making which is both environmentally and economically sound [3]. The result is that organisations working in the same country or in the same discipline collect similar data in different ways, engage in much duplication of effort, suffer from insufficient or inappropriate standards, or are insufficiently aware of methods that should be used, or of the availability of existing data.

Legal and Policy Issues

The population and development pressures that coastal areas experience generate a number of critical problems and policy issues and raise serious and difficult challenges for coastal planners. In many parts of the world, access to detailed information about the coast is considered a very sensitive issue, primarily due to concerns over national security. These restrictive national security and pricing policy regarding marine and coastal data lead to coastal data being withheld from stakeholders and the general public.

Other issues also need to be taken into account, including the need for harmonised data access policies and exploitation rights for spatial information, particularly that collected by public sector agencies across different nations and even within single governments. Accordingly this complex, fragmented regulating framework for marine and coastal management causes the inability to adequately handle the pressure of different activities and stakeholders within the coastal zone.

CONCLUSION

The lack of accurate information that seamlessly cross the land-sea interface creates a serious obstacle for coastal zone managers. These managers need precise, accurate, and timely data and products that are easily accessible and
usable for a wide variety of applications. In this regard a continuous up-to-date and high resolution terrain model extending from the land, through the littoral zone to the sea would be needed. Such a model will facilitate planning, management, conservation and administration of complex coastal region.

There is a growing need to develop the seamless SDI model as one platform instead of two to increase the efficiency and effectiveness of the management and administration of the land, marine and coastal environment. However, the differences in the marine and terrestrial environments in fundamental datasets, data collection and technology used in these environments will make interoperability and integratability between marine and terrestrial spatial data a big challenge.

In the terrestrial domain, the need to share and integrate spatial data for more efficient resource information management has been recognised for over a decade. There is now increasing recognition by the public at large of the need to support sustainable development of the coastal and marine environments as well. At the moment the practical implementation of a marine SDI is mainly occurring separately to the terrestrial SDI, using the same components but adapting them to suit the different environment. However the multidisciplinary interactions in the land–sea interface require sophisticated information infrastructures that not only do not yet exist, but which will not appear if disciplines continue to develop their SDIs in isolation from one another. Research now needs to focus on combining these initiatives and developing a seamless SDI. The development of a seamless SDI will ensure this data is interoperable and thus improve decision-making and administration in the coastal and marine environments. However for creation a seamless SDI, a number of technical, institutional and policy issues would need to be overcome in order to facilitate the management of the land sea interface.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the support of the members of the Centre for SDIs and Land Administration at the Department of Geomatics, the University of Melbourne and the Australian Research Council (ARC), Linkage-Project on Marine Cadastre, in the preparation of this paper and the associated research. However, the views expressed in the paper are those of the authors and do not necessarily reflect the views of these groups.

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