Applications of GIS for Integrating the Social and Natural Sciences for Decision Making in Coastal Management

The concept of integrated coastal zone management (ICZM) as a widely accepted model for addressing the multitude of anthropogenic and natural factors affecting the world’s coasts has emerged in the last 10 years (Cicin-Sain and Knecht, 1998). Specifically, "integrated management of coastal and marine areas" was called for by Agenda 21, the global template for sustainable development that resulted from the Earth Summit meeting in Rio de Janeiro in 1992. Congruent with ICZM has been the emergence GIS, which quickly became recognized as a technology that facilitates the ICZM process. "Integration" in ICZM is a multi-faceted concept in that it relates to a number of different factors affecting the coastal management process that must be coordinated in order to result in holistic decision-making. Typically, when applying the ICZM approach, coastal managers attempt to achieve integration at the following five levels: intersectoral, intergovernmental, spatial, international, and science-management (Cicin-Sain and Knecht, 1998). GIS is an applicable tool for facilitating the latter form of integration.

Information from both the natural and social sciences is imperative to informed decision-making. However, given the inherent differences in the research methods, interpretative tools, and format of data from the social and the natural sciences, lack of understanding and coordination between the two disciplines can complicate coastal management. These sciences do not always correspond. Integrating information from them requires large sets of diverse data. Many of these data can be depicted spatially (i.e. habitat type, population distribution, development etc.). GIS, therefore, allows for a geographically unified database that depicts this information in formats that make them compatible for analysis and comparative assessment. The discussion below provides an overview of a selection of papers that lend support to the use of Geographic Information Systems as important tools for integrating these different types of information in order to facilitate comprehensive and informed ICZM.

Applications of GIS for coastal management are numerous including fisheries management (Caddy and Carocci, 1999, Morales and Freire, 2003), decision making related to marine protected areas (Cowie-Haskell and Delaney, 2003, Stanbury and Starr, 1999, Villa et al., 2002), vulnerability and risk assessment (El-Raey, 1997, Price et al., 2000, Zeger et al., 2002, Zeidler, 1997), coastal development (Frihy, 1996), training in environmental management (Gumbricht, 1996), user conflicts in coastal areas (Jelsinki et al., 2002), measuring anthropogenic impacts (Porter et al. 1997, White et al., 2003), and integrating local knowledge and human perceptions (Scholz et al., 2003, Shafer and Benzaken, 1998, Stanbury and Starr, 1999). It is not uncommon for a variety of these factors to be included in ICZM activities and many authors stress the validity of GIS for integrating them in a geo-spatial data format (Caddy and Carocci, 1999 Cowie-Haskell and Delaney, 2003, Douven et al., 2003, Frihy, 1996, Jelsinki et al., 2002, Scholz et al., 2003, Stanbury and Starr, 1999). The
articles cited above make use of GIS data in both raster and vector format, depending which is more applicable to the data being depicted.

GIS for ICZM is not always used in isolation but has been integrated with a variety of other data sources and decision-making tools. Examples in the literature include remote sensing and surveys (El-Raey, 1997, Frihy, 1996), Multiple Criteria Analysis (Villa et al., 2002), statistics (Goodchild, 1993, Jelsinki et al., 2002), and environmental simulation modeling (Stayaert, 1993). However, many will argue that the most important aid to GIS decision-making is human reasoning (Gumbricht, 1996, King and Kraemer, 1993, Porter, et al., 1997).

The utility for GIS in coastal management lies not only in it's effectiveness as a data management tool, but in it's ability to portray data in a spatial format that can be visualized to aid in management decisions (for example Caddy and Carocci, 1999, Douven et al., 2003, Frihy, 1996, Gumbricht, 1996, Stanbury and Starr, 1999). GIS can be used to portray different management scenarios, to make temporal comparisons and for predicting the impacts of different factors on the coastal environment (for example Caddy and Carocci, 1999, Cantú et al. 2004, El-Raey, 1997, King and Kraemer, 1993, White et al., 2003). Its flexibility also allows for interactive and adaptive management in that new data can be added to portray emerging issues and scenarios (Morales and Freire, 2003).

Along with the flexibility associated with its applications, GIS can be accessed by a wide spectrum of users. However, this brings up an important factor in that the presentation of GIS data for effective use in coastal management is extremely important (Cowie-Haskell and Delaney, 2003, Douven et al., 2003, King and Kraemer, 1993, Zerger et al, 2002). For example Douven et al. (2003) and Morales and Freire (2003) advocate the use of GIS at a community level. In order to be effective, these data must be presented in a format that can be understood by a wide audience. Without proper presentation, GIS data is not user friendly which negates one of its most important uses as a decision making tool. As suggested by Zerger et al. (2002), computer generated maps can imply a level of accuracy not inherent in the data. Furthermore, social data is not always easily translated into spatial context. Important decisions must be made by the person creating the GIS model or map so, as mentioned previously, the reasoning of the person(s) involved is very important in ensuring that the data are put to the best possible use.

As evidenced by this brief overview GIS, in combination with other tools, is very important for integrating data from the natural and social sciences for ICZM. If used in the right way, GIS represents an inexpensive, effective and reliable method of storing and portraying digital data to facilitate coastal management (Ricketts, 1992, Scholz et al., 2003, Villa et al., 2002). There is no question that GIS will continue to be imperative to ICZM and, as is the trend with most technology, I expect that the software will become more advanced, user-friendly and compatible with complementary decision-making tools, thus increasing the utility and extent of GIS in this field.

ANNOTATED REFERENCES
Caddy, J.F., and F. Carocci. 1999. The Spatial Allocation of Fishing Intensity by Port-
Based Inshore Fleets: A GIS Application. ICES Journal of Marine Science
56: 388-403.

This paper looks at the applications of GIS as a decision making tool for fisheries
management. Specifically, it is used to integrate and analyze interactions
between data from ports, inshore fleets, and in local non-migratory inshore
stocks. This application clearly illustrates the flexibility of GIS and its utility as a
modeling framework and decision making tool. The model is used to aid
discussion between fisheries managers, lending support to the benefits of
visualizing spatial data for conceptualizing management options. The author
stresses an important limitation of GIS in that it cannot be used as a simulation
tool bit simply to provide scenarios.

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This article is useful in the sense that it provides a specific example of how
scientific information was incorporated into designing a marine reserve. GIS was
critical in the process of integrating different datasets (i.e. biological, economics)
into maps of the same scale. The author does emphasize the importance of
choosing the right GIS model and framework suited to the data, lending support
to importance of the role of human reasoning in translating digital data into a
meaningful model for use in coastal management.

Zone Management: The Example of the Banten Bay Seagrass
Ecosystem, Indonesia, Ocean and Coastal Management 46: 615-634.

The author summarizes the main premise that geo-information technology is
useful to ICZM, "because it can process large amounts of spatial data and can
integrate different types and sources of data". This paper provides a useful
overview of how GIS can benefit ICZM using the specific example of the Banten
Bay seagrass ecosystem in Indonesia. This approach provides a tangible
application of the concept of GIS as an integrative data management and
decision making tool and illustrates it's applicability to both ICZM and ecosystem
management. The overlays used for the GIS analysis were derived from social
and natural sciences including sea grass density, commercial fish habitat, near
past and planned shoreline development. The author stresses the importance of
GIS for ICZM decision making at the district level by using it to compare past and
present situations, for selection of monitoring sites, and for the processing of monitoring information in Banten Bay.


This paper provides a useful example of how GIS can be used in collaboration with other information sources to aid coastal management decisions. Specifically, the author uses the analysis to propose a coastal management scheme for new resort beaches along the Nile Delta coast using data for erosion and accretion. The author proposes a database management system using a combination of remote sensing, field methods and GIS used to inform management decisions. He suggests that, "this system integrates different information sources in order to use all available data simultaneously in the analysis of coastal management problems". The paper contains a useful flowchart that generalizes steps for establishing the proposed coastal management information system (COMIS).


This is a pilot study that assesses GIS as a tool for integrating fishermen’s knowledge into the MPA planning process in California. The issue of incorporating local knowledge into management decisions is rife into the academic literature making this an important and relevant example of the use of GIS. The authors provide methods of collecting fishermen's knowledge, standardizing it and integrating it into the policy process and for combining biological and socio-economic information to aid management decisions.


Although this paper does not specifically use GIS as an analysis tool, it is interesting in that it used the logic of GIS to building three social coverages for institutional mapping -- scale (spatial), power (social), and capital (cultural)). The term "mapping" is not used literally, but in the broader sense of delineating. The author claims the institutional approach is necessary for ecosystem management and looks at four institutions affecting watershed management: salmon restoration, water quality improvement, forest management and land-use planning. The author writes that "successful institutions require matching human dimensions and ecological requirements" and that institutional mapping can be used to evaluate the effectiveness of institutions trying to improve watershed health.

This article presents the case study of Monterey Bay National Marine Sanctuary to show how GIS can be used for habitat assessment and marine resource management. A combination of socio-political and ecological data is used to inform management decisions. The authors lend support to the utility of GIS for collating, archiving, displaying, analyzing and modeling spatial and temporal data. Further, they site GIS as a way of integrating scientific data with cultural values and traditions. The database created in this study is useful in that is can be built upon and used for decision making in the future.


This paper is very interesting as it proposes a method for integrating two important decision making tools -- GIS and multiple criteria analysis (MCA). The case of Asinara Island National reserve is used to illustrate how this method can couple stakeholder interests and GIS spatial data into coastal management decisions. A form of MCA, called spatial MCA is used to create maps that represent concordance of an area' characteristics with one or more land use scenarios. The results of this study were used to define an optimal zoning plan for the Marine Reserve.


This paper examines GIS methodologies for predicting flood risk to urban areas from storm surge from tropical cyclones using the case study of Carins, Australia. This is an interesting and applicable study in that is examines the use of GIS specifically to address the issue of uncertainty. Two methodologies are used to account for uncertainty in risk predictions: grid cell uncertainty model and standard probability model. Interestingly, the spatial results were almost identical but techniques differ in computational overheads and implementation efficiencies. The authors stress the important point that computer generated maps can imply a level of accuracy not inherent in the data. This article provides an applied example of the importance of choosing the right model for GIS analysis.
ADDITIONAL REFERENCES


Shafer, S.C., and D. Benzaken. 1998. User Perceptions about Marine Wilderness on

