Brest
9-11 septembre 1999

actes de colloques 25

Coordinateurs
Jacques Populus
Lionel Loubersac

CoastGIS'99: Geomatics and coastal enviroment

25

Ifremer

SHOM FRANCE

CoastGIS'99
Geomatics and coastal environment

CoastGIS'99
Géomatique et environnement littoral

Coordinateurs :
Jacques Populus, Lionel Loubersac

Actes de colloques
Brest, 9-11 septembre 1999

Ifremer

SHOM FRANCE

Préface

Étienne Cailliau[1], Bruno Barnouin[2]

(1) Directeur de l'établissement principal du Shom
(2) Directeur de l'environnement et de l'aménagement littoral de l'Ifremer

L'importance scientifique, sociale et économique de la connaissance et de la gestion du littoral n'est plus à découvrir. Cela fait plusieurs années déjà qu'est apparu clairement, dans le milieu scientifique ainsi que dans ceux des décideurs et des écologistes, le besoin de connaître et de décrire plus précisément le littoral, considéré ici en deçà et au-delà du trait de côte. Il s'agit de l'appréhender, l'expliquer, l'occuper, l'exploiter, le gérer, le protéger. En cette fin de millénaire, on assiste à une prise de conscience par la société de l'importance et de la fragilité de cette partie essentielle de la planète. Nous réalisons tous qu'il faut connaître et comprendre ce milieu, prédire ses évolutions afin de pouvoir y vivre, y travailler mais aussi œuvrer pour sa préservation à court, moyen et long termes.

Des outils scientifiques et techniques performants sont désormais disponibles pour appréhender le contexte des phénomènes qui contrôlent l'espace littoral et décrire les processus eux-mêmes. Ce sont ces modes d'observation, ces modèles de gestion, ces systèmes d'information géographique qui ont été présentés et débattus pendant les journées CoastGIS'99.

Les documents d'introduction de cette conférence CoastGIS'99 mettent très justement l'accent sur la multiplicité des acteurs, des demandeurs comme des fournisseurs d'informations. Les expériences de l'Institut français de recherche pour l'exploitation de la mer et du Service hydrographique et océanographique de la Marine dans le domaine de la géohydrographie littorale montrent ainsi que rares sont les demandeurs qui ont une notion précise de leurs besoins et de ce qui leur sera réellement utile. Plus rares encore sont ceux qui ont clairement identifié les ressources financières qu'ils auront à consacrer à la gestion de l'information : l'acquisition de cette connaissance géohydrographique, son entretien et sa mise à disposition coûtent cher, et le prix est d'autant plus élevé que le besoin des utilisateurs est souvent spécifique et que l'information doit donc être acquise, interprétée et présentée différemment selon chaque usage particulier.

Évidemment, la collecte des données d'observation peut et doit être optimisée, qu'il s'agisse des contextes géographique, physique, géologique, géophysique, du contenu biogéochimique, des aspects économiques, sociologiques, écologiques et juridiques. Cette synergie des observations impose une démarche forcément pluridisciplinaire, des protocoles spécifiques et des standards communs, et donc une stratégie de coopérations transverses, nationales, régionales, européennes et internationales très fortes, ainsi qu'une homogénéité d'actions entre l'amont et l'aval, entre les fournisseurs et les utilisateurs de l'information.

Enfin, il n'est pas inutile de rappeler que cette information décrivant l'espace littoral, objet des présentations et des débats de CoastGIS'99, est par nature variable et fluctuante, à toutes les échelles de temps et d'espace. C'est la prise en compte de cette dynamique qui représente sans doute le défi le plus important par rapport aux pratiques cartographiques traditionnelles. Le travail qui nous attend est donc considérable.

Sommaire

Présentation de l'ouvrage

Le colloque CoastGIS'99 « SIG et gestion intégrée du littoral : méthodes et moyens » s'est tenu à Brest en septembre 1999, après Cork en Irlande et Aberdeen en Écosse. La manifestation a réuni environ 150 participants. On a choisi de rassembler dans cet ouvrage une sélection de 26 documents parmi les quelque 62 communications orales et posters. Ces textes ont été retenus par le comité scientifique du colloque, puis organisés en quatre chapitres.

L'introduction ainsi que l'article de conclusion ouvrent puis alimentent la discussion sur les problèmes fondamentaux relatifs à l'information géographique côtière en général, mais surtout sur les avantages et les contraintes associés à sa forme numérique.

Le premier chapitre aborde les multiples facettes de l'organisation de l'information en « systèmes ». De quelle information s'agit-il, entre donnée d'origine et produit final ? Comment bâtir les bases de données et leurs catalogues ? Comment, grâce aux nouvelles technologies de réseau, encourager le dialogue entre producteurs et utilisateurs ? Enfin, comment accroître la compatibilité de leurs moyens et favoriser l'aide à la décision ?

L'avènement de méthodes numériques, autant pour l'acquisition de données que pour leur représentation à des fins opérationnelles, ouvre un champ de recherche considérable. Le deuxième chapitre en donne quelques illustrations.

La diversité des problématiques abordées au troisième chapitre est représentative du dynamisme des équipes. En particulier, dans le domaine de l'évolution du littoral, les SIG sont utilisés à l'inventaire synthétique des milieux et à la modélisation des risques encourus sous l'effet de la mer, en fonction de paramètres géographiques mais aussi socio-économiques. Dans le domaine purement aquatique, la mise en relation entre modélisation et SIG permet de mieux aborder les questions délicates d'évaluation de la qualité du milieu, pour lesquelles le facteur temporel est incontournable.

Enfin, le quatrième chapitre traite des aspects légaux et réglementaires où les SIG sont un instrument clé pour assurer une représentation objective de la complexité des systèmes de régulation, grâce à leurs possibilités de mise en relation des textes de lois et de leur espace d'application.

CoastGIS'99 est une étape significative dans la prise de conscience de la valeur de l'information relative à l'aménagement des espaces côtiers, mais aussi de ses enjeux scientifiques, techniques, économiques et sociaux. CoastGIS se poursuivra en 2001 à Halifax au Canada.

Introduction

Keynote lectures

Communication générale

Informations géographiques et références associées

Michel Le Gouic

Epshom, 13 rue du Chatellier, BP 426, 29275 Brest Cedex, France - mlegouic@shom.fr

Résumé

Expliciter de façon satisfaisante les référentiels utilisés pour décrire ou quantifier les objets traités par les systèmes d'information géographique n'est pas aussi aisé qu'il y paraît, alors qu'il s'agit d'une information essentielle. Cette communication vise à illustrer et non à détailler une problématique épineuse qui rend à la fois complexe l'utilisation croisée d'informations et approximative une application s'appuyant sur des données insuffisamment définies.

Abstract

Although it is essential to clarify the frames of reference used to describe or quantify objects processed by Geographic Information Systems, it is not as easy as it may seem. This paper sets out to illustrate this difficult issue, and not to provide a detailed description. The problem complicates the use of crossed information and leads to inaccuracy in applications relying on inadequately defined data.

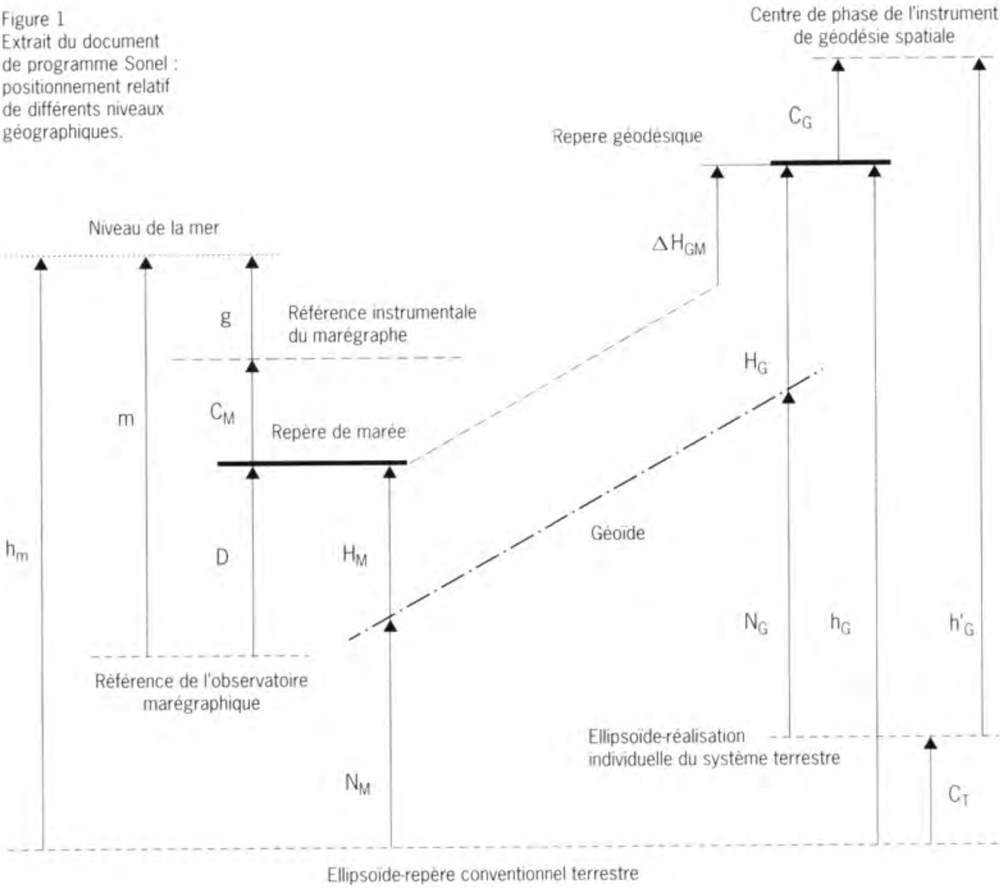
Introduction

Il sera question au cours de ces journées de SIG, d'objets, de relations entre eux, d'évolutions temporelles ou spatiales, de couches d'information se complétant ou fusionnant. Implicitement, tout ceci suppose l'existence de références permettant un réel rapprochement des divers éléments entre eux. Ces références ne sont pas seulement d'ordre géographique (système géodésique, unité de mesure, modèle de géoïde...) : elles concernent également le vocabulaire utilisé pour désigner les éléments et leurs relations, le type de traitement effectué aussi bien lors de la mesure que pour la mise à disposition des données, les méthodes et moyens employés à l'époque de l'observation, les objectifs qui ont conduit à effectuer les mesures... Les quelques exemples simples qui suivent visent à illustrer la nécessité de définir avec précision le cadre de référence que constituent les métadonnées.

La définition des objets

Prenons l'exemple du trait de côte. Sa définition suppose une clarification avant même de parler d'évolution ou de limite de responsabilité. Pour le géographe terrestre, il peut s'agir de l'altitude zéro au-dessus du niveau moyen des mers. Par construction, l'origine du réseau français du nivellement général de la France (NGF) est le niveau moyen observé à Marseille, anse Colvo, promenade de la Corniche. Notons déjà que, entre la première détermination du réseau de nivellement à partir de 1860 par Bourdalouë et celle de Lallemand, une différence de sept centimètres est observée, qui ne correspond aucunement à une quelconque variation du niveau de la mer est observée.
Ce réseau est ensuite extrapolé par mesures de nivellement de proche en proche, recalées sur les observations marégraphiques au voisinage de la mer. Le résultat de cette extrapolation est fonction des moyens et des méthodes mis en œuvre et, entre Bourdalouë et Lallemand, on observe des écarts de 60 cm en Bretagne.
Pour l'hydrographe, il s'agit normalement du niveau des plus basses mers, niveau qui varie géographiquement avec l'amplitude de la marée. La référence pour le trait de côte, défini cette fois comme la profondeur zéro (Wöppelman *et al.*, 1999) et donc pour toute la bathymétrie, n'est pas constante par rapport à la référence du géographe terrestre et donc aux altitudes.
Pour des raisons pratiques, ce référentiel marin n'est pas défini continûment mais pour des zones dont le nombre a été arrêté pragmatiquement afin de minimiser les discontinuités entre zones adjacentes et les variations d'écart avec la référence des altitudes.
En outre, le souci premier d'un service hydrographique est la sécurité de la navigation. Le zéro hydrographique est donc conventionnellement choisi un peu au-dessous des plus basses mers astronomiques afin que le navigateur dispose en permanence d'au moins la quantité d'eau indiquée sur les cartes marines. Ce « un peu au-dessous » est laissé à l'appréciation de l'ingénieur hydrographe et il peut aller en France jusqu'à 60 centimètres. On peut noter que le « un peu au-dessous » est généralement nul en Grande-Bretagne et qu'il se traduit pour l'accès à Europort en Hollande par 50 cm au-dessus…
On peut bien sûr établir un lien quantifié entre zéro hydrographique et zéro géographique et la figure 1 illustre quelques-unes des mesures qui sont nécessaires pour ce raccordement.
Les cartes géographiques montrent une limite qui est aussi qualifiée de trait de côte. Elle représente la limite de végétation ou le bord d'une falaise et est donc qualitative. Proche de cette limite, une notion souvent confondue à tort avec le trait de côte est la limite du domaine public maritime. En France, elle est bornée depuis Colbert (ordonnance de 1681) par « les limites atteintes par le plus grand flot de l'année ». Pour la déterminer physiquement, on utilise une « armée » de piétons qui marquent les zones inondées lors des marées astronomiques les plus proches du coefficient 120 (cas typique lors de la vive-eau

Figure 1
Extrait du document de programme Sonel : positionnement relatif de différents niveaux géographiques.



d'équinoxe de printemps). Mais on observe alors un combiné de la marée astronomique, des conditions météorologiques (surcotes ou décotes) et d'autres phénomènes connexes comme la surcharge gravimétrique. La marée astronomique est déterministe, les effets météorologiques sont eux probabilistes. Pour un même coefficient de 119, les limites seront ainsi variables dans le temps.

On introduit ainsi une quatrième appréciation du trait de côte qui associe les effets déterministes et probabilistes : la notion de niveau extrême, très utile pour les aménageurs, permet par exemple de dimensionner les ouvrages portuaires, les installations de protection, ou de déterminer si une situation est de nature « catastrophe naturelle » ou non.

La détermination des niveaux extrêmes (PM et BM) suppose de disposer de séries d'observations de la marée assez longues (encore une autre référence, quelle durée ?), ce qui n'est le cas qu'en un nombre limité de points. Comme ces niveaux extrêmes varient le long de la côte, il est nécessaire d'extrapoler, en utilisant un modèle de marée, les résultats connus en deux points d'observation. Un tel modèle de marée est fortement dépendant de la qualité de la connaissance de la topographie sous-marine, laquelle varie avec l'évolution technologique.

On voit à travers cet exemple du trait de côte qu'il s'agit de bien définir ce qu'on entend par une notion particulière, et sur quelles références géographiques on s'appuie pour la définir. Cependant, il ne faut pas oublier que, si la définition d'une notion peut être stable dans le temps (encore faut-il le vérifier), celle de référence géographique varie avec les évolutions technologique et méthodologique.

L'évolution des méthodes et techniques

À chaque époque, on essaie d'obtenir un compromis raisonnable entre la satisfaction des besoins recensés et les moyens à consacrer à cette tâche. Pour revenir à la détermination des altitudes, il était demandé à Bourdalouë d'établir un réseau de premier ordre de 25 000 km, avec un intercalaire représentant, lui, 840 000 km de nivellement relatif. Au rythme honorable de 1 500 km par an, il y avait là plusieurs siècles de travaux ! (Levallois, 1987).

La technologie ne permettant pas la satisfaction idéale des besoins à une époque donnée, on ajuste la méthodologie employée pour obtenir un compromis acceptable.

La réutilisation de données anciennes suppose donc que l'on se penche sur la façon dont elles ont été acquises et traitées. En matière de morphologie des fonds, la plupart des levés anciens a été réalisée pour assurer la sécurité de la navigation. La conduite des levés et leur exploitation privilégient la recherche et la représentation des sondes les plus courtes, et une description fine des axes de navigation. Il est des cas où cette distorsion ne nuit pas à une exploitation actuelle des informations anciennes, par exemple pour le suivi temporel de la migration des dunes de sable du Pas-de-Calais. Il est des cas où, au contraire, une réutilisation des données anciennes peut être de nature à fausser les résultats des études sur une thématique connexe, par exemple l'hydrodynamique littorale pour laquelle, d'une part, la modélisation n'a que faire des routes les plus fréquentées et, d'autre part, la pertinence des résultats est contrainte par les zones de moindre connaissance.

Le triplet (X, Y, Z) indique qu'à la position X, Y, la profondeur est de Z mètres. Ce n'est pas suffisant pour une exploitation claire de cette information. L'époque du levé permet de connaître la technologie donnant accès à une mesure de la profondeur et de la position, ainsi que les corrections qui ont été appliquées : marée, célérité du son, étalonnage du moyen de localisation, etc. Elle permet de connaître les règles méthodologiques qui ont été appliquées dans la définition des routes de sonde, dans la mise en œuvre éventuelle des moyens de détection complémentaires et dans le choix des sondes à conserver. Le type de levé (reconnaissance, hydrographie générale, levé d'une route d'accès à un port, levé d'une voie recommandée...) permet d'estimer la probabilité qu'au voisinage de la sonde il y ait ou non des têtes plus courtes. L'échelle du levé donne une idée de la densité des travaux, de la précision relative de localisation. Ce sont des informations essentielles qui constituent un cadre de référence et qui, dans les fichiers numériques, se traduisent en métadonnées.

Si l'on prend par exemple un levé de l'entre-deux guerres sur la côte nord de Bretagne comme celui repéré c dans le diagramme des sources de la figure 2, les observations ont été faites avec un plomb de sonde ; outre l'imprécision sur la mesure, le risque d'omettre une remontée significative du fond est réel. La marée a été estimée par cartes cotidales empiriques en référence à un observatoire distant de plusieurs dizaines de kilomètres, dont les données peuvent être discontinues (aléas mécaniques) et ne sont pas réduites des phénomènes météorologiques. Si la position est assez proche de la côte, la localisation X, Y sera en général de bonne qualité mais, si l'on se trouve hors de portée optique, la précision sera très vite dégradée. Dans ce cas, le levé sera de toute façon à échelle réduite, typiquement du 1/30 000, c'est-à-dire avec une ligne de sonde tous les 300 mètres. Comme aucun moyen de détection latérale

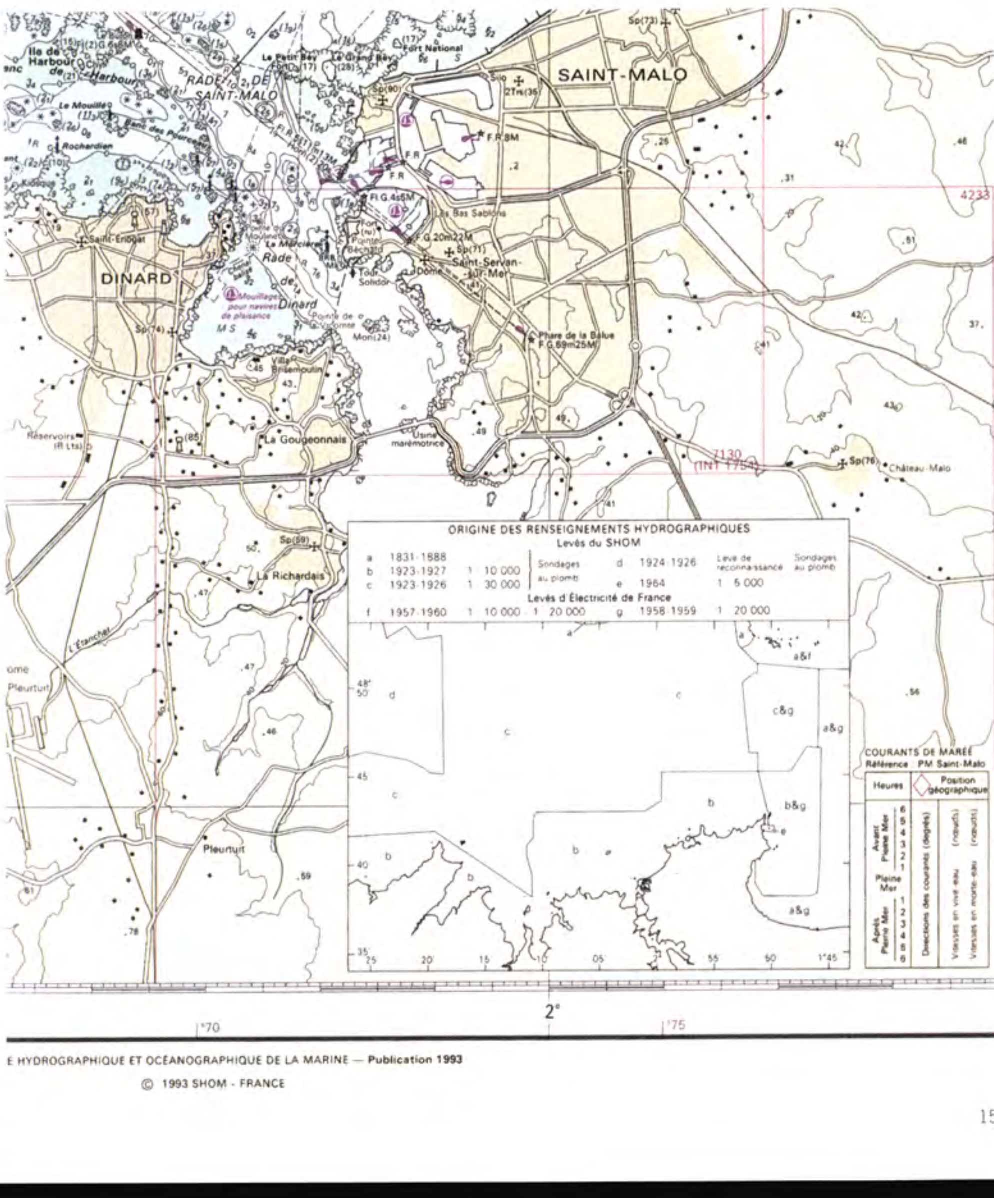


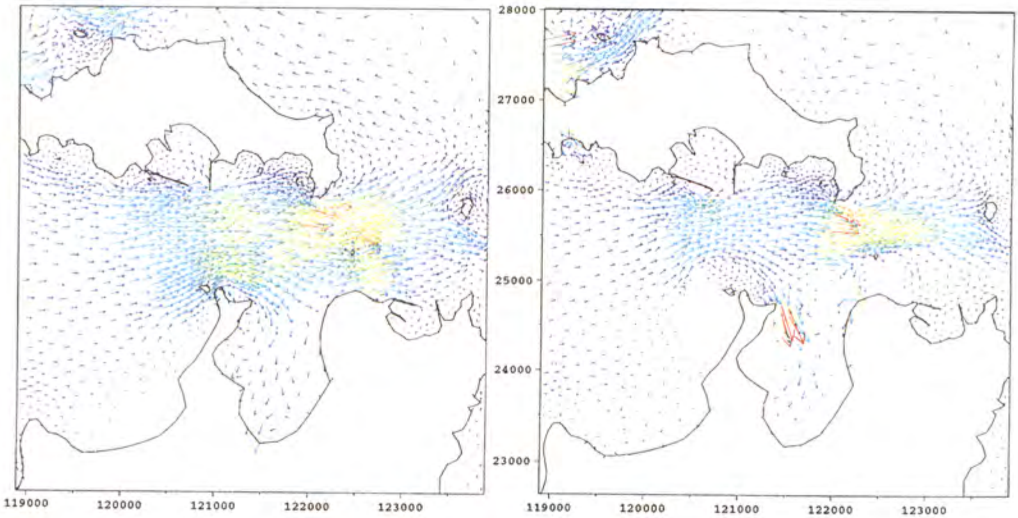
Figure 2
Diagramme des sources de données de la carte marine Shom 7155 : Approches de Saint-Malo.

n'est mis en œuvre (drague, sondeur latéral, sonar, magnétomètre...), l'échantillonnage transversal réalisé ne permet que de dresser une morphologie générale des fonds et l'échantillonnage longitudinal, le long du profil de sonde, aura privilégié les points hauts.

À travers cet exemple, on voit très bien que l'utilisation de données géographiques suppose que l'on connaisse la façon dont elles ont été acquises afin de pouvoir estimer la confiance que l'on peut apporter pour l'utilisation projetée.

De plus, il est essentiel de savoir la façon dont ces données géographiques ont ensuite été traitées pour être mises à disposition. Si cette mise à disposition se fait à travers une carte marine, le cartographe aura généralisé les données de sorte que le navigateur soit incité à utiliser les zones les plus sûres. La figure 3 montre le résultat d'une modélisation hydrodynamique utilisant dans un cas les données observées et, dans l'autre cas, ces mêmes données interprétées par un cartographe marin. Dans les deux cas, les paramètres d'évaluation de la qualité du modèle mathématique sont satisfaisants mais les courants sont, eux, très différents.

Figure 3
Modélisation des courants : à gauche bathymétrie originale, à droite bathymétrie de la carte marine.



L'imprécision des références

Pour illustrer cet aspect des références, prenons un dernier exemple : celui des décrets et arrêtés relatifs au domaine maritime. Cette réglementation est essentielle en matière de gestion du littoral puisqu'elle permet de protéger, d'exploiter, de contrôler, de développer, d'aménager ou d'organiser une zone à l'écologie fragile. Les SIG côtiers destinés à divers responsables (ministères, collectivités territoriales, concessionnaires...) doivent intégrer ces aspects réglementaires, à la fois dans le constat des situations mises en place et dans la préparation de leur

évolution. Les textes relatifs à cette réglementation doivent être précis de manière à ne pas laisser d'ambiguïté quant à leur interprétation, permettre une utilisation facile par les usagers et ne pas dépendre de paramètres difficiles à maîtriser (édition de cartes, modification de balisage, disparition d'amers...). En pratique, on observe des problèmes nombreux qui sont liés aux références géographiques utilisées et qui sont sources de difficultés importantes pour la cohérence et l'applicabilité de la réglementation :
- références géographiques : mélange de points pris sur la carte marine et sur la carte terrestre, absence d'indication des systèmes géodésiques, positionnement relatif, etc. ;
- nature des limites : une ligne droite est-elle une orthodromie ou une loxodromie ? Un cercle est-il un lieu d'égale distance à un point donné ou une ellipse dont la représentation en projection est un cercle ? Le trait de côte est-il celui des hydrographes ou celui des géographes ? Une limite de distance à la côte est-elle une parallèle à celle-ci ou l'enveloppe d'égale distance ?
- incohérences dues à une excessive redondance (alignement et points de coordonnées géographiques) ou à des repères mobiles (bouées pouvant éviter ou être déplacées...).

Conclusion

En conclusion, on n'a pas cherché ici à définir de façon exhaustive ou théorique les difficultés liées à une explicitation insuffisante des références utilisées en matière d'information géographique. On aurait pu de façon analogue commenter la relativité des données de référence dans tous les domaines traités en milieu littoral : géodésie, positionnement en mer, gravimétrie, magnétisme, nature des fonds. Il s'agissait plutôt d'illustrer que de détailler une problématique épineuse qui rend à la fois complexe l'utilisation croisée d'informations et approximative une application s'appuyant sur des données insuffisamment définies.

Références bibliographiques

Levallois J.-J., 1987. Mesurer la terre : 300 ans de géodésie française. École Natl. Ponts et Chaussées.

Wöppelman G., Allain S., Bahurel P., Lannuzel S., Simon B., 1999. Zéro hydrographique : vers une détermination globale. Rev. XYZ, 2e trimestre.

Systèmes d'information géographique et gestion intégrée des zones côtières

François Cuq
IUEM, laboratoire Géosystèmes, UMR 6554, place Nicolas Copernic, 29280 Plouzané, France
Francois.Cuq@univ-brest.fr

Résumé

Après trente années de recherche sur la gestion intégrée des zones côtières, force est de constater que la mise en œuvre de ce concept a pris un retard considérable, malgré l'intérêt affirmé de la majorité des États de la planète.
Absence de volonté politique ? Difficulté à envisager la prise en compte simultanée de l'ensemble des composantes naturelles et humaines du système côtier ? Ces deux questions sont certainement pertinentes. Cependant, si l'on considère que les systèmes d'information géographique (SIG) offrent un cadre conceptuel, méthodologique et opérationnel adapté pour l'aide à la gestion intégrée, il semble nécessaire de dresser le bilan de leur réelle capacité à prendre en compte les conditions scientifiques et techniques nécessaires à l'appui de la prise de décision.

Abstract

After thirteen years of theoretical and applied research on integrated coastal zone management, it must be noted that implementation of the concept has significantly fallen behind, despite the interest declared by the majority of States worldwide.
Lack of political will? Difficulty taking into account all the natural and human components of the coastal system? These two questions are certainly relevant. However, if we consider that Geographic Information Systems (GIS) offer a conceptual, methodological and operational framework which can support integrated management, it seems necessary to assess their real ability to take account of the scientific and technical conditions required to support decision making.

Introduction

Les réflexions sur la gestion intégrée des zones côtières ont débuté avec l'US Coastal Zone Management Act, en 1972, et la convention de Ramsar soutenue par Bird Life International, le Fonds mondial pour la nature (WWF), l'Union mondiale pour la nature (UICN) et Wetlands International. Cette convention, aujourd'hui ratifiée par 116 États, a été fortement relayée par la conférence des Nations unies sur l'environnement et le développement de Rio, en 1992, et par les déclarations de Noordwijk, en 1993, et de Lisbonne, en 1994. De nombreuses

organisations internationales se sont engagées à promouvoir les principes de précaution et de développement durable qui sous-tendent cet engagement.
Si des progrès importants ont été faits sur le plan de l'approche théorique de la gestion des zones côtières, avec en particulier la publication de manuels méthodologiques (Clark, 1995 ; IOC, 1997), il apparaît cependant que sa mise en pratique se heurte à des difficultés majeures. Peter Burbridge (1998), lors de la troisième conférence européenne sur les sciences et les technologies marines de Lisbonne, en mai 1998, évoque deux obstacles principaux :
- le développement trop timide de l'action politique pour la gestion des relations complexes entre écologie, économie et société sur le milieu littoral ;
- le manque d'informations scientifiques adaptées - ou plutôt la difficulté de diffusion et de vulgarisation des informations - concernant le fonctionnement des écosystèmes côtiers et les relations écologiques complexes entre les systèmes marins et terrestres.
Sur le plan de la recherche, c'est à partir du début des années soixante-dix que quelques centres, comme le Coastal Resource Center (University of Rhode Island, États-Unis) ou l'International Institute for Infrastructural, Hydraulic and Environmental Engineering (Delft University, Pays-Bas), se sont spécialisés dans l'étude des milieux littoraux et de leur gestion, mais l'intérêt de la communauté scientifique pour les zones côtières ne s'est véritablement développé qu'à partir du milieu des années quatre-vingt. En France, un effort important a été consenti avec la création du programme national d'océanographie côtière (PNOC) et des programmes nationaux qui complètent son action. Le relais a été établi avec le programme ELOISE (European Land-Ocean Interactions Studies), contribution au programme international LOICZ (Land-Ocean Interactions in the Coastal Zone).
Malgré les résultats scientifiques obtenus au cours de ces dernières années, on constate après dix ans de recherche une difficulté à développer l'ouverture pluridisciplinaire nécessaire, en particulier en ce qui concerne le lien entre sciences du milieu et sciences humaines, ainsi que le constataient récemment Barnouin & Chardy (1998).
Si l'on se réfère à l'expérience internationale dans ce domaine (Bartlett, 1993 ; Canessa, 1998 ; Cuq, 1993 ; Furness, 1995 ; Jordão *et al.*, 1996 ; Klemas *et al.*, 1995 ; Staljanssens, 1998), il apparaît que les principales avancées concernant la prise en compte simultanée des conditions écologiques et humaines se sont fortement appuyées sur les SIG, outils scientifiques et techniques fédérateurs qui ont permis d'établir un lien tangible entre les différents compartiments des systèmes étudiés. Il est cependant intéressant d'analyser leurs capacités réelles à prendre en compte le contexte scientifique global du fonctionnement des systèmes littoraux, en le traduisant sous une forme directement exploitable pour mettre en place des systèmes d'aide à la décision en matière de gestion des zones côtières.

Le contexte scientifique de l'aide à la gestion intégrée de l'environnement côtier fait référence à deux domaines :
- la part du monde réel qu'il est nécessaire de modéliser pour simuler les interactions dynamiques du système étudié ;
- le mode de représentation de l'information qui permet d'établir une relation fonctionnelle entre les composantes du milieu et les actions humaines.
Sur le plan de la mise en œuvre du système d'information, il convient de préciser les aspects suivants :
- quel est le modèle de données qui permet de décrire les relations dynamiques entre les différents compartiments du système étudié selon des échelles spatiales et temporelles pertinentes ?
- quelles sont les données nécessaires à la constitution des bases d'information géographique adaptées à l'aide à la gestion intégrée ?
- quelles sont les conditions techniques de la modélisation couplée entre composantes naturelles et anthropiques prenant en compte les changements à long terme de l'environnement ?

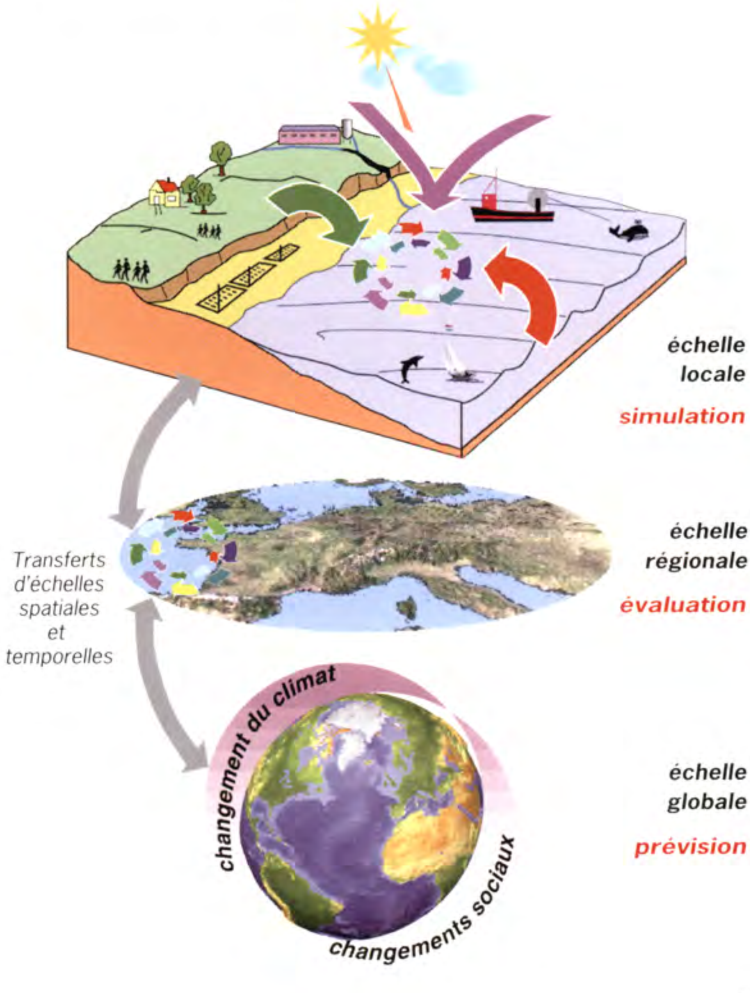
Un modèle de réalité pertinent

Une bonne décision en matière de gestion de l'environnement côtier doit aboutir, à partir d'une connaissance détaillée des interactions à court, moyen et long termes, à maintenir ou à améliorer globalement l'état du système dans la perspective de l'entretien des ressources renouvelables et du développement durable. Partant de ce préalable, on peut définir les conditions initiales nécessaires à la description du modèle de réalité que l'on veut construire. Son élaboration repose sur une prise en compte précise du système étudié, des relations entre ses différents compartiments et des processus dynamiques qui le structurent. Cette description doit s'appuyer sur une analyse de la pertinence des échelles spatiales et temporelles qui permettront de décrire le fonctionnement global du système.
Les systèmes côtiers sont généralement complexes et leur situation à l'interface entre l'océan, la terre et l'atmosphère impose la définition d'un modèle de réalité très élaboré. Afin de dégager la structure générale de ce modèle, il semble nécessaire d'utiliser une démarche qui prenne en compte la nature des relations que l'on veut décrire, les échelles spatiales des processus dynamiques et les composantes temporelles de l'évolution du système. Cette démarche peut s'appuyer sur les trois fonctions principales que suppose l'aide à la gestion intégrée (voir figure) :
- simuler l'impact direct d'un aménagement sous des conditions variées ;
- évaluer les conséquences d'une décision sur l'équilibre du système côtier ;
- prévoir les tendances à long terme de l'évolution.

• La fonction de simulation de l'impact direct d'une décision d'aménagement est au cœur du système d'aide à la gestion intégrée. Le noyau du modèle doit être constitué par une description fine des processus dynamiques, afin de pouvoir mesurer rapidement l'évolution d'indicateurs utilisés pour valider ou invalider la décision à l'échelle locale. Il nécessite donc la disponibilité d'informations précises, à haute résolution spatiale, caractérisant les composantes biologiques, physiques ou humaines du système.

• L'évaluation des conséquences d'une décision sur l'équilibre du système côtier impose l'intégration sur une période significative des interactions à haute fréquence temporelle entre la nature et la société en replaçant le cadre local de la décision dans le contexte régional du système traité. Cela concerne la mise en relation des domaines suivants :
- description dynamique de la circulation des eaux littorales, en relation avec le transport sédimentaire, la qualité biogéochimique des eaux et les composantes biologiques de l'écosystème ;

Un modèle de réalité pour la gestion intégrée des zones côtières.



- description dynamique de l'utilisation du milieu par les sociétés humaines, en relation avec l'appropriation des ressources renouvelables, la compétition entre les différentes activités et les rejets côtiers des sous-produits de l'activité anthropique.
L'objectif est de mesurer les conséquences indirectes d'une décision de gestion afin d'en évaluer l'impact à moyen terme dans un cadre géographique élargi.

• Prévoir les tendances à long terme de l'évolution impose la prise en compte d'une approche prospective globale qui envisage à la fois la résultante des variations locales et régionales du système côtier, mais aussi les changements climatiques et sociaux à long terme. Si l'on commence à disposer de modèles décrivant l'évolution du climat, il est beaucoup plus complexe d'envisager une modélisation à très long terme dans le champ économique et social (Bousquet *et al.*, 1996). La définition de scénarios, fondés sur des repères ou des objectifs de gestion, semble donc être la voie la plus réaliste de l'approche des changements à long terme de l'environnement côtier.
Comme on peut le constater, la définition d'un modèle de réalité pertinent pour la gestion intégrée des zones côtières prend en compte des échelles spatiales variées et des durées allant du court au long termes, en préservant un lien fonctionnel entre ces différentes échelles spatiales et temporelles et en adaptant le niveau de détail et la précision des informations selon le niveau d'analyse souhaité. Outre la complexité d'un tel modèle, sa mise en œuvre repose sur le choix de formalismes communs pour la description des composantes naturelles et anthropiques.

La représentation de l'information

Le second aspect théorique de l'aide à la gestion intégrée des zones côtières concerne le problème de la représentation de l'information. On pourrait penser *a priori* que l'utilisation d'un SIG comme outil de gestion et d'analyse impose l'emploi d'une forme de représentation commune à l'ensemble des agents dynamiques afin de pouvoir décrire leurs interactions. Dans cette perspective, l'une des solutions prônées au début des années quatre-vingt-dix était le recours à la représentation de l'information en mode maillé, la résolution variable de la maille devant permettre de compenser les différences d'emprise spatiale des objets à une échelle d'analyse donnée. Or, si l'on peut en partie s'affranchir des problèmes de changement de résolution à l'intérieur d'un même domaine scalaire par l'utilisation de maillages hiérarchiques imbriqués, l'ensemble des entités, des phénomènes ou des objets étudiés ne peut véritablement être représenté sous la forme unique de surfaces thématiques si l'on veut préserver la structure et la nature du modèle de réalité.
Au-delà du simple refus d'une dégradation de la représentation par l'emploi d'une représentation unique, il faut aussi envisager l'existence de plusieurs perceptions du même modèle de réalité selon le point de

vue adopté. Ces différentes perceptions conduisent à admettre la représentation multiple d'une même information, suivant l'échelle, le pas de temps ou l'angle thématique considérés. Il est donc nécessaire de représenter les objets sous différentes formes, liées principalement à l'échelle d'analyse, en établissant un lien fonctionnel entre ces différentes représentations.

En outre, pour des raisons pratiques liées à la mise en œuvre de modèles dynamiques couplés, il faut utiliser des formes de représentation transitoires adaptées à l'analyse spécifique d'un système d'interactions sur un espace donné. On sera donc amené à transposer temporairement des informations de nature et de résolution diverses en les représentant sous la forme de surfaces (polygones, maillages réguliers ou imbriqués, tessélations) afin de répondre aux contraintes techniques de l'application de procédures d'analyse.

Au-delà de la recherche d'un mode de représentation unique de l'information, on envisagera plutôt les conditions d'interopérabilité entre informations de nature et de forme différentes et l'intégration de ces formalismes multiples à l'aide de schémas conceptuels adaptés.

Un schéma conceptuel ouvert

La mise en œuvre effective du système d'information dépend de la capacité du modèle de données à mettre en relation les entités définies par le modèle de réalité précédemment décrit. La modélisation entité-association se traduit par la construction d'un schéma conceptuel décrivant les relations fonctionnelles entre les différentes entités. D'autres modèles de données peuvent être utilisés pour décrire ces relations. Dans le cas précis d'un SIG dédié à la gestion de l'environnement côtier dont le schéma conceptuel est particulièrement complexe, il semble préférable d'utiliser un modèle simple qui sépare la description logique de la base d'information de sa structure physique.

Le modèle relationnel (Codd, 1970) présente de grands avantages par sa structure en tableaux, l'emploi d'opérateurs simples et intuitifs sans développement de procédures complexes, et l'indépendance des applications vis-à-vis de l'implantation physique des données. Ce modèle présente néanmoins certaines limites concernant la gestion des objets complexes et/ou dynamiques et un problème de défaut d'impédance lié à la représentation des relations par des tableaux.

Pour pallier ces défauts, deux autres modèles de données peuvent être utilisés : le modèle orienté objet et le modèle relationnel étendu :

- le modèle orienté objet définit une nouvelle famille de système de gestion de base de données, les SGBD-OO (Gorman & Choobineh, 1991). La structure de base utilisée pour le modèle d'entité-association est l'objet, équivalent des tableaux du modèle relationnel. Un objet comprend à la fois l'information et les traitements qui peuvent lui être appliqués, l'information n'étant accessible qu'au travers de ces traitements. C'est le procédé d'encapsulation du contenu d'un objet. Les objets se regroupent en classes, chaque classe caractérisant une structure commune de représentation des attributs. Ces classes peuvent posséder des

sous-classes qui leur sont liées par un procédé d'héritage. Une sous-classe reprend la structure de sa classe « mère » en y ajoutant des attributs et des traitements. Enfin, chaque objet possède une identité, analogue à la clé primaire du modèle relationnel, sans pour autant que cette identité soit liée à la structure des attributs ;
- le modèle relationnel étendu, directement issu du modèle relationnel, y ajoute des fonctionnalités de type objet (Cattell, 1991). Il est ainsi possible de créer des types de données abstraits qui lient la nature de l'information aux traitements qui peuvent lui être appliqués en intégrant un mécanisme d'encapsulation. À ces nouveaux types de données sont associées de nouvelles requêtes au sein du langage de gestion et d'interrogation de la base de données.

Des études ont été consacrées aux avantages respectifs de ces deux modèles (Duhl & Damon, 1988). Les bases de données objets ont des structures plus proches du modèle de réalité et permettent donc une meilleure représentation des entités complexes ; la notion d'héritage permet la préservation de la qualité sémantique du schéma conceptuel et l'encapsulation des objets facilite la mise à jour des bases de données. Cependant, dans le cas d'un système de gestion intégrée à vocation généraliste, le modèle objet présente actuellement des inconvénients qui interdisent pratiquement son utilisation : complexité et non-standardisation des structures de données, ce qui limite considérablement l'interopérabilité des bases d'information ; manipulation procédurale de l'information, ce qui accroît énormément la complexité de l'analyse.

Le modèle relationnel étendu, bien qu'il garde les principaux défauts du modèle relationnel, est donc actuellement la solution la plus fréquemment retenue pour garantir l'existence d'un schéma ouvert.

Abondance des données et pertinence de l'information

Au risque de sembler paradoxal, on peut affirmer qu'un SIG n'a pas besoin de données, du moins pas directement. Il a besoin d'informations, c'est-à-dire d'ensembles de données mises en forme, prétraitées et normalisées, renseignées et de qualité connue. Cette distinction entre la notion de donnée et celle d'information est essentielle car elle explique les raisons pour lesquelles, en dépit de l'abondance toujours croissante des données concernant l'environnement côtier, il n'existe, en pratique, que très peu d'informations réellement utilisables à des fins de gestion (Furness, 1994).

La production d'informations constitue en pratique la phase la plus longue et la plus ingrate de la mise en œuvre d'un SIG. Lorsqu'on applique un traitement, on admet implicitement que les informations concernées par ce traitement appartiennent à un ensemble comparable du point de vue de leurs qualités géométrique et sémantique (Goodchild & Jeansoulin, 1998). Si tel n'est pas le cas, chaque traitement provoque un accroissement progressif du « bruit de fond » des erreurs cumulées jusqu'à ce que le bruit soit plus important que l'information elle-même, rendant alors le système inutilisable.

Du point de vue de l'état des informations destinées à une exploitation au sein d'un SIG, et sans faire référence à leurs modes d'acquisition ou aux coûts induits, on peut souligner les principales difficultés rencontrées pour accéder à une information pertinente.

• En ce qui concerne les informations de référence, on se heurte à cinq obstacles principaux :

- la non-exhaustivité de la couverture spatiale des informations à l'échelle locale ;
- l'absence de continuité spatiale entre les domaines terrestre et marin, tant du point de vue de la délimitation du trait de côte que de celui des niveaux hypsométriques de référence ;
- le niveau d'agrégation des statistiques socio-économiques qui, le plus souvent ramené à la commune, impose le recours à des processus de désagrégation relativement lourds ;
- les délais de mise à jour, rarement compatibles avec les préoccupations de gestion intégrée de l'environnement ;
- l'absence ou la pauvreté des données décrivant ces informations - métadonnées - ce qui rend leur exploitation très difficile.

Il est donc tout à fait urgent de mener des politiques volontaires, aux plans national et international pour développer la production d'informations de référence de qualité garantie.

• Du point de vue de l'imagerie satellitaire, si l'offre en matière de résolution spatiale, de bandes spectrales et de répétitivité ne cesse de s'accroître, les conditions d'intégration des images au sein de bases d'information présentent encore de réelles difficultés, tant du point de vue du prétraitement des données que de celui de la mutation sémantique entre états de surface et information environnementale (Cuq & Gourmelon, 1996). Dans le courant des années quatre-vingt-dix, un effort important a été mené, principalement à partir de données à faible résolution spatiale mais à haute répétitivité temporelle, pour définir des produits directement assimilables au sein de modèles numériques. Cet effort doit être repris en prenant en compte l'apport des nouveaux capteurs embarqués pour ouvrir l'éventail des produits d'images directement intégrables au sein de bases d'information (couleur de l'eau, morphologie de l'estran, occupation et usage des sols, etc.).

La plupart des données disponibles sont généralement difficilement accessibles, peu renseignées, et souvent très disparates du point de vue de leur représentativité spatiale, des protocoles de mesures utilisés et de leur continuité temporelle.

Pour résoudre ces différents problèmes, il est indispensable de continuer à sensibiliser les décideurs pour qu'une politique concertée de constitution d'informations de référence puisse être mise en place en facilitant les relations entre organismes producteurs de données, en dynamisant les réseaux d'échange de données et le catalogage de l'information (O'Donnell, 1996). Dans cette perspective, le développement des normes de catalogage européenne et internationale représente un progrès important, même s'il reste à établir une hiérarchie entre le caractère « obligatoire » ou « optionnel » des métadonnées et à développer la connexion entre ces deux normes.

Du point de vue de la recherche, il est essentiel de promouvoir le développement d'observatoires destinés à acquérir des séries de données à long terme, en normalisant les protocoles de mesures, les nomenclatures et les échelles d'analyse.

Modélisation couplée des interactions entre nature et société

L'un des principaux enjeux de la recherche en matière d'aide à la gestion intégrée des zones côtières concerne la modélisation des interactions entre les actions humaines et le milieu, dans la perspective des objectifs de gestion évoqués précédemment.

On ne dispose pas de modèle permettant de décrire l'ensemble complexe des comportements humains, des mécanismes de décisions et de l'évolution des rapports de force au sein d'une société. Il apparaît donc nécessaire, dans un premier temps, d'envisager l'impact des sociétés sur le milieu en isolant, même de façon artificielle, la part la plus déterministe des activités humaines de son contexte social et culturel.

Si l'on considère que les différentes utilisations professionnelles ou récréatives du milieu peuvent être décrites de façon précise dans le temps et dans l'espace et que ces utilisations soient relativement stables à court et moyen termes, il devient alors possible d'envisager la modélisation couplée des interactions entre les usages et le milieu.

La modélisation des usages peut être abordée sous différents angles. Une première approche consiste à aborder le problème sous l'angle économique de l'impact d'un système de production sur le milieu, en terme de production ou de consommation de biens (au sens large). Cette démarche, héritée des modèles de production jointe (Neumann (von), 1995), a été récemment employée pour analyser la durabilité du développement de sociétés rurales africaines (Chéneau-Loquay & Matarasso, 1998).

Une autre approche se fonde sur l'emploi de modèles basés sur la théorie du jeu et l'intelligence artificielle dont l'objectif est de simuler des agents autonomes et évolutifs en situation d'interaction mutuelle. Cependant, les systèmes multi-agents sont principalement employés pour des opérations de simulation opérationnelle appliquée à des processus se déroulant en temps quasi réel, et doivent donc être adaptés à une modélisation sur de plus longues périodes.

La modélisation de l'utilisation anthropique du milieu sera donc principalement opérée à l'aide de modèles qualitatifs fournissant des résultats vraisemblables, dans la mesure où la recherche du réalisme en matière de modélisation des comportements humains semble peu crédible.

La modélisation du fonctionnement physique et biologique du milieu repose, en zone côtière, sur le choix d'un modèle quantitatif robuste présentant des résultats réalistes et reproductibles. Les principaux critères pour sélectionner un modèle hydrodynamique parmi ceux qui sont actuellement disponibles sont les suivants :

- modèle déjà bien validé ;
- aptitude aux variations de résolution ;
- prise en compte des bancs découvrants ;
- forte aptitude au couplage sédimentaire et/ou biologique ;

- bonne aptitude au forçage par des couches d'information géographique et des images satellitaires.
Le principe du couplage des deux modèles à l'aide d'une plate-forme SIG repose sur leur capacité à échanger des informations selon des formes connues et sur la coordination de leur exécution, qu'elle soit simultanée ou successive, selon les pas de temps considérés et les niveaux d'interactions dynamiques. Le SIG fournit en outre un moyen commun d'étalonnage des modèles et facilite leur validation en gérant les séries de données spatiales décrivant les états successifs du système étudié.

Conclusion

La conception d'un modèle de réalité reposant sur la prise en compte des interactions entre les usages et le milieu à différentes échelles de temps et d'espace est la condition du développement d'un système d'aide à la gestion intégrée des zones côtières. À ce modèle de réalité doit correspondre un modèle de représentation des informations qui se traduise par une structure opérationnelle de base de données.
La pertinence de l'information et sa qualité sont les points essentiels de la mise en œuvre du système et conditionnent la nature des résultats.
L'intégration des composantes humaines, physiques et biologiques de l'échelle locale à l'échelle globale et des périodes du court au long termes est conditionnée par la mise en œuvre de modèles couplés, tirant partie des importantes capacités de gestion et d'échange de données que fournissent les SIG.
Après bientôt trente ans de réflexions et de recherche, il semble que les conditions théoriques, méthodologiques et techniques soient maintenant réunies pour pouvoir dépasser le stade des tests ou des études pilotes afin de mettre en œuvre de véritables systèmes d'aide à la décision pour la gestion intégrée des zones côtières. Il restera, bien évidemment, à intégrer ces systèmes au sein de la chaîne de décision, en préservant la qualité de l'information et la pertinence de l'analyse qui en est faite.

Références bibliographiques

Barnouin B., Chardy P., 1998. Éditorial de la lettre PIGB-PMRC, 7, avril 1998.

Bartlett D.J., 1993. GIS and the coastal zone: an annotated bibliography. NCGIA report 93-9. Santa Barbara, CA, National Center for Geographical Information and Analysis (NCGIA).

Bousquet F., Barreteau O., Mullon C., Weber J., 1996. Modélisation d'accompagnement : systèmes multi-agents et gestion des ressources renouvelables. Actes du colloque « Quel environnement au XXI^e siècle ? Environnement, maîtrise du long terme et démocratie ». Abbaye de Fontevraud, 8 p.

Burbridge P.R., 1998. Provocateur's comments on transforming theories of integrated coastal management into practice. 3rd Eur. Mar. Sci. Technol. Conf., May 98, Lisbonne.

Canessa R.R., 1998. GIS decision support for integrated coastal management. Oceans conservation report series. Integrated coastal zone management - Marine protected areas - Marine environmental quality. DFO, Ottawa, 176 p.

Cattell R.G.G., 1991. Object data management: object-oriented and extended relational database systems. Addison-Wesley Publishing (ed.), Reading, Massachusetts.

Clark J.R., 1995. Coastal zone management Handbook. New York, Lewis publishers (ed.).

Chéneau-Loquay A., Matarasso P., 1998. Approche du développement durable en milieu rural africain. Coll. Études africaines, L'Harmattan, Paris, 267 p.

Codd E.F., 1970. A relational model of data for large shared data banks. Communications of the ACM, 13(6).

Cuq F., 1993. L'utilisation des systèmes d'information géographique pour l'analyse du fonctionnement des écosystèmes. *In:* Les systèmes d'information environnementale. Icalpe, 63-68.

Cuq F., Gourmelon F., 1996. Conditions d'intégration des données satellitaires au sein de bases d'information géographique. Rev. Géomatique, 6(4), 349-363.

Duhl J., Damon C., 1988. A performance comparison of object and relational databases using the sun Benchmark. OOPSLA'88, Conf. Proc., special issue of SIGPLAN notices, 23(11), 153-163.

Furness R.A., 1994. Data access for effective coastal zone management: A cri du cœur for openness. Cartogr., 23(1), 11-18.

Furness R.A. (ed.), 1995. CoastGIS'95: Proceedings of the international symposium on GIS and computer mapping for coastal zone management. Feb. 1995, Cork, Ireland.

Gorman K., Choobineh J., 1991. The object-oriented entity-relationship model. J. Manage. Inf. Systems, 7(3), 41-65.

Goodchild M., Jeansoulin R. (eds), 1998. Data quality in geographic information: from error to uncertainty. Université de Provence, 192 p.

IOC, 1997. Methodological guide to integrated coastal zone management. Manual and guide 36, Intergovernmental oceanographic commission, Unesco, 47 p.

Jordão L., Antunes P., Videira N., Santos R., Martinho S., Pires P., 1996. GIS based decision support for ICZM: Costa Vicentina case study. Conference on socio-economic benefits of integrated coastal zone management, Bremen.

Klemas V.V., Gantt R.G., Hassan H., Patience N., Weatherbee O.P., 1995. Environmental information systems for coastal zone management. World Bank, Washington, DC. XIII +, 104 p.

O'Donnell A., 1996. The Coastal data directory: towards a shared information infrastructure. *In:* Proc. 15th Intern. Conf. Coastal Soc. Alexandria. Bigford T.E., Boyles R.H. Jr., (eds). The Coastal Society, 630-631.

Neumann (von) J., 1945. A model of general economic equilibrium. Rev. Econ. Studies, 13(1).

Staljanssens M., 1998. ICOMIS: A modeling tool for better decision making on coastal zone development. Intercoast network, 29.

GIS Web technologies for delivery of coastal zone information

Roger A. Longhorn
IDG (UK) Limited, EC Projects Office, Neihaff, 9161 Ingeldorf, Luxembourg
ral@alum.mit.edu

Abstract

It is impossible to manage the coastal zone without use of Geographic Information (GI) in a variety of different forms, from different sources, presented to end-users in different ways for different purposes. Manipulating GI is the role of Geographic Information Systems (GIS) and a host of related technologies ranging from remote sensing to digital image processing, from techniques for modeling the processes under investigation to advanced data visualization tools for presenting the results. This paper examines the extent to which GIS tools and related Information and Imaging Technologies (IIT) have advanced in recent years. Can these new tools assist the researcher and manager in Integrated Coastal Zone Management (ICZM), especially in regard to delivery of information in a variety of ways, useful for a wide range of purposes, *via* appropriate media and mechanisms? Are current GIS and related ITT tools sufficient for the information processing and dissemination tasks facing these people, especially in regard to the temporal aspect of coastal zone GI? Are there barriers to making these tools more useful and can such barriers be removed? Is putting GI on the Web the key issue, or only one way in which the Internet can be useful? The paper concludes with a list of problems and potential barriers to better and wider use of the Internet for Coastal Zone (CZ) information discovery, processing and dissemination.

Introduction

Coastal Zone Management (CZM) and research would be very difficult to achieve without access to large volumes of raw data of many different types, whether land-based, ocean-based, at the land-ocean interface or the ocean-air interface. This data is often very expensive to collect, regardless of the methods employed (field survey or remote sensing by aerial photography or satellite imagery). Like many other environments, the coastal zone undergoes continual change, often requiring important data to be collected repeatedly, and sometimes quickly, *e.g.* for real-time disaster management. Data collection, processing and response times can be highly dynamic, *e.g.* involving CZ status during tidal changes. Such temporal data needs are not commonly found in related areas of environmental management and research, such as urban planning, agriculture and forestry.

In the process of converting CZ raw data into coastal zone information (CoZI), the value of the information often derives to a very large extent from the spatial relationships connecting a data item (the attribute) to the physical environment. One of the main functions of a Geographic Information System (GIS) is to help manipulate and to present the raw data in ways which translate the "data" into "information". This paper does not focus on the many problems related to collecting and managing coastal zone information *via* a GIS (or *via* any other paper- or computer-based mechanism), but rather at the ability of GIS tools to disseminate relevant CZ information at appropriate scales, in acceptable time frames, to aid in decision making.

But collecting and processing CZ data is only the starting point. Once data has been converted to information, that information must somehow be presented to many different types of user, from laypersons with little or no appreciation of either IT or GIS to experts in CZ process modeling and management. For example, the level of GIS needed to help raise awareness of CZM issues amongst the public or at a local government meeting does not necessarily need to be as sophisticated as that used for research or management purposes. For widest impact, CZ information dissemination programmes should work quickly, effectively and easily, *via* the Web or CD-ROM (using a Web browser interface), especially as more and more people are becoming familiar with Web browsers. CZ information dissemination tools need to have "consumer product" ease (of installation and use) and desktop software packages such as Microsoft's MapPoint 2000 could be key, ubiquitous tools for future use by non-experts. In an excellent text covering many examples of Web-enabled GIS and related tools, Brandon Plewe (Plewe, 1997) uses the term "distributed geographic information" (DGI) to refer to the widespread distribution of GI in any form, from the simplest "free hand" maps on a Web page to network based collaborative GIS "in which GIS users at remote locations share common data and communicate with one another in real time".

Base maps and thematic data

To fully understand the problems and potential benefits in using the Internet and Web-enabled software to deliver CZ information to users, it is necessary to first look at the characteristics of the types of data being processed. To analyse coastal zone data spatially and to present the resulting information to decision-makers require access to a relevant 'base map' onto which the thematic data is "mapped". This is true whether you are working *via* the Internet and World Wide Web or locally on an in-house intranet, *via* a CD-ROM on your local workstation or directly from the hard disk for your desktop application. A number of questions immediately arise in relation to the base maps and to how the thematic data is collected or derived and then presented.

Do you use raster or vector maps - or both? If both, how do you combine them? Would you like to drape some remote sensing imagery (a raster picture) over the base map(s)/vector data? Vector data (point, line and area) is often used for base maps because: (a) it is more flexible, (b) it is needed to implement true spatial analysis algorithms in most GIS toolsets, and (c) it can be scale independent. However, vector data does not always convey the full message or range of messages suited to a range of information users, without considerable extra-work needed to make it more presentable. Raster maps look good, are easier for non-experts to understand (just like our road maps), have good presentation features (colour, texture, etc.), but are scale dependent. "Zooming" in or out may be interesting, but image quality degrades and the viewer may not necessarily be seeing a true representation of the actual scene.
Other problems arise in relation to base maps, vector data sets or raster images (aerial and satellite imagery). Do you have dissemination rights to the underlying maps or to the new maps or views created using the raster data? In the UK, Ordnance Survey's (OS) NetMap is the only OS data set you can legally use on the Internet and the prices vary considerably depending upon the type of use. Some forms of dissemination or re-use are contractually prevented.
Analysis of a problem often requires locating and combining maps or spatial data of quite different types, such as hydrographic maps, nautical charts, land-use maps, vegetation cover imagery, etc. If these are not already available in digital format, as many will not be, then there is a digitization procedure to complete before a GIS or other data visualization software can use the data. Even where data is already in digital format, how does the user determine if it is at the appropriate scale, with similar and known levels of quality, timeliness, accuracy, precision, etc.?
Don't forget that "maps" are not the only way to convey spatial information or coastal zone information. New technology offers the possibility to present information using Virtual Reality (VR), 3D representations, animations (2D and 3D) and combinations of maps and images, video and sound.

GIS as information dissemination/presentation tools

Using GI and GIS *via* the Web is becoming much more common, with substantial growth in the number and variety of products available since they first appeared less than three years ago. However, despite what the toolsets propose to offer, most current Web-based interactive GI applications are relatively simple in nature, permitting GI data location (from Web-based metadata), downloading of small volumes of GI (images and vector data) and on-line viewing of maps based on simple spatial queries (such as "where is 'A' located?"). There is less practical experience with posing and satisfying more complex spatial queries in a client/server environment *via* the Internet or intranets.

The requirements to implement Distributed Geographic Information (DGI) cover at least five types of activities:
1. GI metadata held on, and distributed *via*, the Web (or an intranet). Problems in creating metadata to emerging standards still exist and must be overcome in the near future, as well as finding new and better ways to access the metadata itself;
2. GI data itself distributed *via* Web servers (Internet or intranet) or *via* a combination of CD-ROM data and Internet/intranet connectivity. The main problems here are related to both the volume of data involved (especially for raster based images) and "access" barriers, such as legal restrictions to data use and re-use, pricing schemes, etc.;
3. "Simple" spatial queries from a client that are satisfied on a remote GI data server, with the answer sent back over the Web (or in-house intranet) to the client;
4. Complex spatial analyses executed solely on a remote GI server where both data and applications software are located, the answer being transmitted back to the client *via* the Internet or an intranet, in response to a query posed by the client. The client PC normally requires only rather simplistic Graphic User Interface (GUI) software;
5. Complex spatial analyses executed using both client (local user's PC) and remote server application software and data.
Most major GIS vendors now have "GI Web server" capability in their product lines (Plewe, 1997). Many different types of user are now trying to use GI *via* the Web or corporate intranets, but users need considerable expertise and special GIS software to overlay different map layers of the same geographic region. The Open GIS Consortium(OGC), champions of GIS interoperability, realized that consensus among GIS software vendors would permit such overlays and combinations of complex and essentially different kinds of geographic information to occur automatically over the Web, despite differences in the vendors' geographic data storage, analysis, and display systems. Their Web Mapping Testbed initiative, involving both vendors and users, was demonstrated to senior US officials in September 1999. At the demonstration, Thomas Kalil, Special Assistant to the US President for Economic Policy at the White House National Economic Council, noted that, "Geospatial information is critical for disaster management, crime mapping, environmental monitoring, community decision-making, and a whole host of other public and private sector applications. The Web Mapping Testbed will greatly accelerate our ability to access and understand geospatial information from multiple sources." (McKee, 1999).
The importance of this and similar initiatives was summed up by David Schell, President of OGC, noting that "... as the value of a Web browser increases with the size of the Web, the value of an on-line GIS or an online collection of geographic data increases with the number of Web-based software systems that can access it through OpenGIS interfaces. Soon Web users will be able to use their browsers to seamlessly access, view and exploit the vast, diverse and widely distributed geospatial

data holdings and geoprocessing resources on the Web. This will have a profound effect on the market for geospatial data and services." (McKee, 1999).

What are the trends?

As a guide to the future, we should look at the underlying trends in Information and Communications Technologies (ICT) which effect those GIS developments which are encouraging wider use of GI in both enterprise and stand-alone applications.

• Advances in GIS development follow those in ICT hardware, software and telecommunications development, generally. Current PCs are now as powerful as graphics workstations were only two or three years ago.

• The Internet has had a profound effect on the way users want to be able to access data - even if they cannot yet do so - easily - today! Whether accessing remote data sources *via* the global Internet or *via* an internal intranet, the same software and hardware can be used (at the user end of the link), encouraging developers to produce ever more powerful applications tools. Problems relating to moving large volumes of data across the Internet due to lack of bandwidth are being addressed in various ways, from ever-faster modems as standard equipment on PCs to greater penetration of ISDN links and advances in loss-less data compression technologies.

• The bulk of GI is used today in "enterprise" environments, *i.e.* multiple users connected to shared resources (servers, software, data), typical examples being local government authorities, departments in national government agencies, utilities companies, travel organizations, and many more in very diverse sectors. These departmental users today commonly operate in an enterprise Client/Server IT environment.

• Single-user, desktop GI/GIS is growing, especially in very small businesses, but this still represents a small part of the overall GI/GIS market place. However, as more and more stand-alone GI users connect to the Internet as a data source, they are actually becoming "clients" in a client/server environment, where the Internet is the "server".

• One of the GI market areas that will see substantial growth in the next decade is that of direct sales of specific GI to individuals *via* the Internet (or a combination of CD-ROM and Internet). There is already evidence for this in the remote sensing sector of the GI market, where large volumes of raster image data are being made available on encrypted and "locked" CD-ROMs, from which the user selects only that piece of GI of interest - and pays accordingly. Ordnance Survey's GB already permits clients to purchase individual "strips" of linear GI from its Superplan digital data product, *e.g.* a single roadway, railway line or power line.

Web enabled GIS toolsets

One of the best sources for information on Web-aware GIS tools, such as Web-enabled GI data servers and client GIS viewing software is available from the Web at *http://www.geog.byu.edu/gisonline/links/soft.htm*, home of Brandon Plewe's "GIS Online" Web site (Plewe, 1997). The server products are often called Internet MapServers (IMS). The following paragraphs simply indicate the type of facilities available in such Web-enabled GIS packages. Reviews of new software and enhancements to existing packages are commonly reported on the Web and in the GIS press.

A distinction should be drawn between simple "point and click" data viewers and systems capable of delivering true GIS (spatial analysis) functionality, *i.e.* offering tools for interaction with the data and to record/respond to user requests. Also, it is important to separate pure image delivery services from the GIS tools provided by many vendors, if only because the hype surrounding some of the new imagery services could lead the unwary (and inexpert) user to believe that image acquisition alone will solve their spatial analysis problems.

AutoDesk offered its Internet enabled GIS publishing suite since 1997, including MapGuide, MapServer, MapAuthor and MapViewer, which handle both raster and vector data. They claim the software "can dramatically increase the value of existing data investments". Environmental firms are a big user. Prices (given here for guideline purposes only) are on the order of 5 000-7 000 Euro for networked MapGuide (server and 25 users) including MapAuthor and some MapViewer use. MapAuthor is 1 000 Euro one off and MapViewer is 40 Euro one off (with full trial versions available from the Web; *http://www.autodesk.com/*).

ESRI MapObjects Internet MapServer (IMS) 2.0 and ArcView IMS are available from the Web, *http://www.esri.com/*. MapObjects IMS adds the ability to serve maps across the Internet to ESRI's existing MapObjects software. It simplifies creating and serving dynamic maps on the Web. The server-based software supports ArcExplorer clients and standard Web browsers, permitting "Net surfers" to use ArcExplorer to interact dynamically with maps or to download GIS data from the server. ArcView IMS is the Web-enabled extension to ArcView, permitting communication *via* the Web and includes the ESRI MapWeb-server extension and MapCafe (basic tools for browsing, exploring and querying maps placed on the Web *via* ArcView IMS).

Intergraph introduced free GeoMedia Viewer in November 1998, which permits Web users to access the extensive range of GIS products available from Intergraph (see *http://www.intergraph.com/infoseek/*). Intergraph offers teaching *via* the Web on its Support Programme (*http://www.intergraph.com/software/support/*) featuring customer forums and links to Oracle and Microsoft training sites. The underlying technology is from GeoMedia Web Map 2.0.

MapInfo, MapXsite and MapXtreme Java Edition released in November 1998 claim to be "the first 100 per cent Java mapping server for the Web" (Microsoft's MapPoint 2000 is based on a MapXtreme engine underneath - and Microsoft owns 25% of MapInfo). Trial versions are available (*http://www.mapxtreme.com/*) and the full package costs on the order of 25 000 Euro for a four-server license.

In summary, hundreds of new Web-based GIS sites are being created and prices of software are dropping. Remote spatial data analysis and display capabilities are increasing. Lots of "bells and whistles" are being added and this will continue. MapInfo and AutoDesk provide third-party, rapid-application-development tools with their map-authoring products. What are now needed are "idiot-proof" set-up procedures? Still, placing "live" maps on the Web is not easy and often requires a significant amount of customization. Do Coastal Zone Management users have that time, skill or resources?

Where do you start? MapInfo and ESRI separate the mapping functions and Web support functions into two modules, which may be easier if you are starting from no pre-existing interactive GIS. Intergraph's GeoMedia Web Map environment excels at combining data sets, permitting you to read several data formats "on the fly", combine vector and raster data into a single map and deliver "smart graphics" across the Web in Active CGM format (Computer Graphics Metafile, a published standard). According to some independent software reviewers, this is one of the few offerings to provide true "clickable" vector data on a Web map.

One thing is certain. The number of Web-aware GIS and data visualization software packages coming on the market is ever increasing, and new spatially enabled functions are being added to existing desktop software at a steady state. We can safely expect most desktop software to be "spatially aware" within the next three to four years. This could have an enormous impact on the ability of Coastal Zone managers to collect, process, make decisions and disseminate results much more cheaply and effectively than is possible today, using often expensive, bespoke software.

Applying "Hi-Tech" tools

The arrival of the Internet and Web, then the Java scripting language and finally Virtual Reality Modeling Language (VRML) have opened exciting new opportunities to use the Web as an animated front-end into a 3D (three dimensional) world for anyone with a standard browser and freely available VRML software "plug-ins" for the browser. Using VRML, an extensive server-based database management system can be served up to users *via* an interactive, real-time, 3D interface using Java Applets (small programmes, written in Java) that run on the user's PC. Inside the Web, the Applet also interacts with the VRML viewer *via* an External Application Interface (EAI).

Using VRML and the Web, it is possible, for the first time, to open up the three-dimensional characteristic of many GI data sets, allowing users to navigate into and through such data in interesting new ways. But creating a 3D "virtual world" for interaction across the Web is not easy and requires all the skills of the GIS professional (to get the spatial relationships correct) as well as new skills in designing Graphical User

Interfaces (GUIs), since each new application essentially becomes a new GUI specifically for that application (Landes, 1999). Virtual worlds are composed of many types of "objects" which are given "properties" to indicate how they can and cannot react to user interactions and with each other and the virtual environment itself.

As opposed to creating new interactive games, instruction manuals, library browsing services and the many other applications that VRML is now being used for, the GIS developer must keep in mind that the placement, sizing, scaling and re-scaling of objects in a GI virtual world are much more important than for a game's developer! While VRML worlds are exciting new ways to present purely visual information to decision makers, the user/viewer may have more trouble in accepting the "vision" thus presented, compared to working with more traditional 2D maps (whether on paper or on screen) and it is more difficult to fully understand the metric nature of the underlying GI.

Examples of GIS in use in Coastal Zone Management (CZM)

Numerous examples exist of using GIS *via* the Web to disseminate and provide collaborative work environments for Coastal Zone Management and research. Two such projects are briefly described below and full details are available from the Web sites indicated. New projects have also begun under the European Union's Fifth RTD Framework Programme, such as Hypergeo (Easy and friendly access to geographic information for mobile users) and CoastBase (the Virtual European Coastal & Marine Data Warehouse). Many examples of using GIS *via* the Web for Coastal Zone Management and marine research can be found at the EC's Centre for Earth Observation's Infeo Web site at: *http://infeo.ceo.org/*.

Desima - Decision Support for Integrated Coastal Zone Management

Desima (*http://desima.jrc.it/html/Home.htm*) aims to design and develop a prototype version of an information system that facilitates the integrated use of various sources of spatially related data and information using Geographical Information System (GIS) techniques and tools, demonstrated by executing two application scenarios related to Coastal Zone Management. The main innovative features are:

- on-line access to data, *via* a user interface allowing catalogue query and on-line data retrieval and transfer to the user;
- on-demand data processing, application dependent, to deliver high level information suited to user needs rather than low-level sensor information;
- a distributed architecture incorporating remote data sets and remote processing.

End-users will benefit from Desima by more efficient decision making, leading to cost and time savings, while assuring sustainable development of natural resources in coastal zones. End-users can economize their investments in human and non-human resources because the Desima distributed architecture does not require that know-how and

informatics equipment are duplicated at the users' sites. Commercial and non-commercial data providers can increase distribution and use of their information, leading to a much better return on investment made for the collection of the information, promoting the development of applications.
The main design features of Desima include:
- "Many to many" relationships between/among data, tools, users, *e.g.* various data, various users, remote access, heterogeneity;
- a fully distributed and interoperable system;
- real time operations, *e.g.* processing on demand, true added value data distribution;
- information resources can be local or a remote archive and repository;
- flexibility, offering the ability to evolve (accommodating new data, new data types, new models, etc.);
- an open system, offering remote processing and remote catalogue services.
To meet these requirements, Object Oriented (OO) technology was selected as a basis for the design, which enforces modularity that promotes software re-use and ensures the ability to evolve.

Thetis Project - Design of a data repositories collection and data visualization system for Coastal Zone Management of the Mediterranean Sea

Thetis is a 30-month project, with a total budget of nearly 2.5 million Euro, which began in July 1997 with partial funding from the Telematics Applications Programme of the European Union's Fourth RTD Framework Programme. Ten partners from four EU member States are involved, as are the MIT Ocean Engineering Department (Cambridge, MA, USA) and the IBM T. J. Watson Research Center (USA).
The Thetis system addresses the frequent requirement of scientists, engineers and decision-makers to access, process and subsequently visualize data held at different locations and collected and stored in different formats. Tools are needed that enable the integration of such data, along with their associated data models, interpretation models, and visualization environments. Because of its heavy focus on the Internet and Web-related technologies, the following paragraphs describe the Thetis system in some detail.
The objective of the Thetis project is to build an advanced integrated interoperable system for transparent access and visualization of data repositories, *via* the Internet and the Web. The system will be a working prototype, demonstrating its ability to respond to assist users of scientific information for decision-making purposes.
"Vast amounts of information exist, collected and processed over many years at different research institutions. The data collections are stored in various databases, files, spreadsheets, or are generated by sophisticated data simulation models, and data processing techniques. These data collections comprise numeric data, images, text documents, audio

and video. Data models are implemented in software program codes, that usually need visualization tools to represent their results".

"The lack of transparent integration means that data is not practically available for integrated problem solving. Increasingly, solutions to problems require data from several disciplines, and also from different regions and countries. One application area where data integration and visualization is particularly needed is in Coastal Zone Management (CZM) and the prototype system will focus on supporting CZM of the Mediterranean Region of Europe." (Quoted from: *http://www.ics.forth.gr/pleiades/thetis/Docs/thetis-paper.html*).

Using the Internet to connect users to a distributed collection of information systems, the main elements of the architectural framework are:

- Web-based access to databases of various kinds, as this provides a simple way to access information of various kinds (HTML documents, images, video and audio) and provides a transparent interface to the users to browse the various information sources. HTML documents can act as indexes to information sources for a large distributed system and extensions to XML should be possible;
- Invoking existing applications, such as simulations, data visualization, GIS related data interpretation, and graphical tools, along with the various GIS tool collections, invoked *via* the Web. (*http://www.iacm.gr/gaea*);
- Access to legacy databases, *via* the Web, which already contain various information, both georeferenced data and images, that store the required coastal information, including data stored in/by Illustra, Sybase, Oracle and Arc/Info;
- Integrate existing services for indexing, searching and access with data repositories and GIS information such as areas/regions of maps selected by the user, *via* a Dienst 4.0 server (*http://cs-tr.cs.cornell.edu/Dienst/htdocs/ document_menu.html*) and a Disco. Metadata standards for digital geospatial metadata such as those of the US Federal Geographic Data Committee (FGDC) will be used (*http://www.blm.gov/gis/meta/barney/meta_sections3.html*), which provide definitions for a number of fields, along with their relations within a hierarchical structure. Another standard, the Usmarc, is used for analog and digital geospatial data. (*http://alexandria.sdc.ucsb.edu/public-documents/metadata/marc2fgdc.html*);
- An interface is provided for information sources that provide data and image collection services common to all users. The goal is to integrate existing technologies within the common platform, *i.e.* the Web, *via* a common Web browser (Netscape) modified for the needs of Thetis. Virtual Reality Modeling Language (VRML) (*http://hiwaay.net/~crispen/vrml/faq.html*) will be incorporated as a tool for visualization across the network;
- Existing technology is used for access restrictions and security, *via* commercially available tools for access authorization and electronic payment capabilities, integrated into the user interface.

The following specific tools are being used:
- the Disco system as the mediator/access engine from INRIA (France);
- the Dienst distributed index and search engine/server (available in the public domain - see Web site above). Appropriate metadata for the CZM data repositories have to be built and the index / search capabilities of Dienst appropriately expanded for the requirements of the Thetis system;
- GIS based on an Arc/Info database with a Web interface, available from partner IACM, Forth (Greece);
- data stored in an Oracle database and Excel spreadsheets are integrated into the Thetis system, as are data concerning satellite images stored in Oracle databases (from ALCATEL, France);
- VRML, a graphics tool, available in the public domain and accessed *via* the Web;
- various simulator tools for data processing and data interpretation are available from IMBC, IACM, INRIA, ALCATEL, and CNR. Specific reference to various such programs/tools for their application content is made at the demonstrator actions;
- the Netscape Web browser is employed as the user interface.

The coastal zone management and research community will be closely watching the level of data and systems integration, and Web-based tools development, achieved by the end of the Thetis project. For latest information, visit the excellent Web site at *http://www.ics.forth.gr/pleiades/thetis/thetis.html*.

Problems and barriers

Three main problem areas exist in regard to better exploiting Internet and Web-enabled technology for coastal zone information.

• Data exchange and interoperability: Major problems still exist, due mainly to legacy data, concerning the ability to exchange and interoperably use multiple data sets, especially from multiple data sources. As far as GIS tools interoperability is concerned, the work of the US-based Open GIS Consortium (OGC) which is developing a wide range of Open-GIS system specifications supported by the entire GIS vendor community (and many large users) is key to resolving many interoperability problems. Although OGC has managed a very effective initiative regarding Web Mapping Testbeds, it rarely focuses specifically on interoperable data issues. (See *http://www.opengis.org*).

• Integration of data with tools: Understanding the coastal zone involves data not only from many different sources, but of many different types, from tables to maps to images, including video and even sound. Very few systems exist today that permit users, at any level of expertise, to easily integrate such diverse data sources and types. Yet it is exactly such integration that often leads to the most impressive and useful form of presentation when trying to educate the public and government about crucial coastal zone problems.

• Metadata and directory services: Far more coastal zone information exists that we will ever be able to access. Users need to create metadata, using available standards, and make such data known to the potential user community *via* metadata directory (or catalogue) services, which must also be created to acceptable standards. The US Federal Geographic Data Committee (FGDC), European Standards Organization (CEN) and now International Standards Organization (ISO) have all defined national, regional and (eventually) global standards for GI metadata. Now it is time for members of the CZ management and research community to prepare metadata for their key (new and on-going data collection) data sets as a matter of urgency, not as something that is done "if there is any time or project funding left at the end of the exercise". Recent research into the ability of search engines to use metadata effectively indicate that much more work needs to be done in regard to creating not only complex metadata, but also viable "discovery" metadata, to acceptable standards such as those provided by the Dublin Core (*http://purl.org/dc/*).
In the US, NOAA's National Ocean Service has published a Revised Proposal for a US National Shoreline Data Standard (March 3, 1998), "primarily oriented towards reaching a common understanding of the shoreline for national mapping purposes and other geospatial (GIS) applications." The metadata will provide a standardized methodology for evaluating shoreline data (regardless of survey methodology or technology) and reporting resultant data quality through a standard quality reporting method. This will permit much wider use and acceptability (sharing) of shoreline data between parties. This will also establish a means (rules) for beginning to establish national shoreline certification program (NOAA, 1999).

Conclusion

In February 1999 Info-Coast'99 brought together over 140 delegates with direct interest in the coastal zone, from 13 European Union member States, with an exceptionally wide variety of expertise and experience. The symposium examined the current situation of information and knowledge management for the implementation of ICZM addressed the major barriers to effective data, information and knowledge flow between the provider and user communities and developed practical recommendations for improving the current inadequate situation. The Executive Summary from the symposium report confirmed that:
- European coastal zone data, information and knowledge networks are generally inadequate in interconnecting users and information providers;
- coastal zone data and information management issues and needs are typical of those elsewhere in the information industry and much can be gained from implementing the common standards currently available and under development for the wider information market;

- improving inputs from local users and access to local knowledge (as well as data and information) are vital components of information exchange networks. It is essential to link the information and knowledge expertise of non-governmental organizations and networks with those of governments and intergovernmental agencies (Info-Coast'99, 1999).

All three of the above concerns can be addressed by improvements in the ability to locate, access, process and disseminate coastal zone information on a wider basis, in forms and formats appropriate to the end-users and to their level of skill and technology. The Internet and Web play key roles in enhancing our (eventual) ability to tackle all three of the problems stated above. GIS and other spatially enabled tools, whether for analysis or simply data visualization, also play key roles. GIS is an integral part of the coastal zone information management and dissemination task. Indeed, nearly all coastal zone information has a spatial component. How are we in the coastal zone community responding to or participating in the GIS and spatial data debates? Is ignorance of the issues and solutions being proposed elsewhere in the information industry still one of our main problems?

Bibliographic references

Info-Coast'99, 1999. Executive Summary, 1st European Symposium on Knowledge and Information Management for the Coastal Zone. Noordwijkerhout, the Netherlands, February 1999.

Landes S., 1999. Access to virtual worlds *via* Internet. GIM International, January 1999, 13, 76-79.

McKee L., 1999. Web Mapping Testbed Demonstration. Open GIS Consortium, Wayland, MA, USA, OGC Press Release, September 1999.

NOAA, 1999. NOAA Coastal Shoreline Website - *http://www.csc.noaa.gov/shoreline/*.

Plewe B., 1997. GIS On-line: Information Retrieval, Mapping and the Internet. Onword Press, 312 p.

GI2000 - Why do we need a European Geographic Information policy?

Yves Reginster
GERE SA, 35 rue J.F. Kennedy, 7327 Steinsel, Luxembourg - Yves.reginster@gere.lu

Abstract

The paper aims at presenting the role of the European Commission in the GI market, and to explain why we need a geographic information policy at European level.
The European Commission has three main roles:
- a stimulation role, through stimulation, research and development programmes, such as Info2000, 5th Framework Programme;
- it is a market actor, making use of geographic information to plan and manage European policies: environment, transport, agriculture, fisheries, etc.;
- it has a political role, defining rules and regulations. It tries to organize the market, creating favourable conditions for a sustainable market growth. The main political initiatives are the Green Paper on access to public data and GI2000, which proposes to develop the European Geographic Information Infrastructure (EGII) and to set up a political leadership with the creation of a High Level Working Party, working with a strong political mandate from each member State.
GI2000 is needed to support the integration of geographic information into the information society, making geographic information common place.
The article presents some examples, illustrating the cost of not having a European geographic information infrastructure, and presents the main guidelines to create one.

Introduction

Managing a territory requires an ongoing decision process and monitoring. The information society enables fast evolution, thus increasing the need for timely and accurate data to be made available, and the need for methods and technologies to exploit data providing relevant information.
Territorial management involves many fields: agriculture, environment, transport, fisheries, land use planning, geo-marketing, geology, etc. The principles of sustainable development, agreed upon at the Rio de Janeiro and Kyoto meetings, have created an increasing need to combine data and information from these different disciplines. Most of this information is related to the Earth.

The only way to succeed in combining data, and to keep coherence in the decision-making process is to create an infrastructure that makes the reference data and system available for all users, from all fields, regardless of the their work's scope (from local, regional, national, European to international level).
From the political point of view, we are still far from having reached true awareness on the part of European decision makers, not to mention achieving a true European Geographic Information (GI) policy. The European Commission (EC) action for GI focuses more on Research and Technology Development (RTD) and market development stimulation. However, we hope that the growing number of national political initiatives will soon act as catalysts for a European GI policy.
Before presenting the arguments for a European GI policy, we will first analyse the role of the European Commission, in the GI context, what is required to successfully integrate GI into the information society and reach a true European GI single market.

The role of the European Commission on the GI market

The European Commission plays three major roles on the market:
- a stimulation role;
- a market actor role, buying and distributing data;
- a political role.

• A stimulation role

The EC launches many programmes aiming at stimulating European economic growth, improving Europe's competitiveness in the global market framework. The Commission's mission, especially DG XIII/E, is to contribute to the emergence of a European information society, stimulating a competitive multimedia content industry, facilitating access to and exploitation of European content resources and building on Europe's culture and linguistic diversity.
To reach such objectives, the Commission has different tools of some interest for the GI market: Info2000 and the 5^{th} Framework Programme (5FP).

Info2000

To stimulate the information market, Info2000 funds several shared cost actions, with strong GI participation. These projects aim at creating information services, contribute to building GI infrastructure and work on interoperability issues improving access to data.
In addition to shared cost actions, the Commission also launched several market surveys to try to assess and better understand the European information market. Three GI specific studies were launched.
The main result of these studies is the difficulty in understanding the market. GI is a complex horizontal market, linked with many other activities. The GI economy is mixed, with strong links between public and private sectors. Finally, there is an important lack of awareness of the GI market's importance in social and economic life.

Fifth Framework Programme for Research and Development (5FP)

The 5FP is now the Commission's major tool to stimulate the competitiveness of Europe, recently organized and fully integrated into four theme-based programmes:

a) Quality of life and the management of living resources;

b) User-friendly Information Society;

c) Competitive and sustainable growth;

d) Energy, environment and sustainable development.

In addition to this first set, the 5FP organizes three other types of activities:

1. Confirming the international role of Community research;

2. Promoting innovation and encouraging participation of small and medium-sized enterprises;

3. Improving human research potential and the socio-economic knowledge base.

GI needs to be fully integrated into the overall EU strategy for the Information Society. GI underpins many of the activities within the four theme-based programmes as well as socio-economic research in horizontal action on Improving Human Potential. Therefore much of the R&D outlined below will be of benefit throughout the 5FP. The core activity is currently situated in the theme-based programme "user-friendly Information Society" (IST Programme). This theme concentrates on activities concerned with development, demonstration and taking-up of information society technologies, including their deployment and application specific integration research, as well as uses in specific domains in the other theme-based programmes.

The IST Programme is organized into four key actions and generic activities:

- KA 1: Systems and services for the citizen;
- KA 2: New methods of work and electronic commerce;
- KA 3: Multimedia content and tools;
- KA 4: Essential technologies and infrastructures;
- cross-programme themes;
- future and emerging technologies;
- research networking.

All details about 5FP are available at *http://www.cordis.lu/*

• A market actor role

An efficient European Geographic Information Infrastructure (EGII) will make the work of many European policy decision makers easier:

- environment, sustainable development;
- transport, GALILEO Programme with Global Navigation Satellite System (GNSS);
- common agriculture policy;
- fisheries;
- space programme (Earth Observation, positioning systems);
- land planning, regional policy;
- European Statistical System.

The EC itself faces the problem of getting access to pan-European data sets, in order to manage and monitor European policies. More and more, regional policies apply at a cross border level; they need an increasing amount of data which is coherent at European level.
In response, the Commission created GISCO, in EUROSTAT, a service aimed at supporting the other services working for different European policies mentioned above. GISCO strongly supports the concept of a European policy for geographic information, in which EGII plays an important part.
All national authorities recognize the need for European co-ordination above each national initiative. The National Mapping Agencies have created two associations (CERCO/MEGRIN) to co-ordinate their action. Umbrella organization for GI (EUROGI) and the association of GI laboratories in Europe (AGILE) have been created to activate the European level.

An overall need for Europe's future policy

The Kosovo war dramatically highlighted the need for action at a European level to keep control of information. Timely, accurate and relevant information is the key element of competitiveness, for all sectors of our society. The information infrastructure is the foundation for this competitiveness.

The transport policy

The European policy for transport follows some objectives that information infrastructure will strongly support:
- the Trans-European Network aims at creating an efficient pan-European transport infrastructure. The design of such an infrastructure requires thorough knowledge of the needs and the parameters necessary for any decision. Most of the required information is spatially referenced. A European transport infrastructure has a huge impact on society and mobility, but also on the environment. Territorial information is the basis for assessing this impact;
- multimodal transport: the main problem faced by the EC is the difficulty in accessing information. The information infrastructure is the foundation for any transport system decision support and monitoring;
- the Commission launched the Galileo programme to develop the European navigation and positioning system: GNSS. Without European and global reference systems and an information infrastructure, it will be less efficient. There is a strong need to keep the links between the European space policy (Earth Observation, GNSS and telecom) and EGII.

Common Agriculture Policy (CAP)

Pressure to optimise the CAP is growing ever sharper with the enlargement of Europe. The EC is starting to control statements and analyse the policy impact on society, economy and environment more carefully. All these analyses require the EGII. Joint use of earth observation and GI technologies has provided a powerful contribution to these objectives.

European Environmental policy

To provide environmental information to support European policy, the European Environmental Agency (EEA) was created. Again, the EEA faces huge problems in obtaining coherent data and information on a European scale. The EGII will help make coherent pan-European data sets available.

Fisheries policy

The EC DG XIV responsible for fisheries is also creating a GIS service to support its policy. They too will need the EGII to be effective.

Regional policy

DG XVI has been one of the first to use territorial data. Like all EC services, they suffer from the lack of coherent and timely data available for the European territory. Also, the EU is now launching a new programme requiring large amounts of territorial information: the European Spatial Development Programme (ESDP).

This list of European policies for which the planning, monitoring and management will be improved is not exhaustive, many other policies, programmes, activities will benefit from the EGII.

• A political role

The Information Society is a global issue. The Commission plays an important political role in defining rules and regulations. It tries to organize the market, bearing in mind sustainability and improving citizens' living conditions.

Such a political role involves many diversified activities. We will focus on two of them:

- Green Paper on access to public data;
- GI2000.

Green Paper on access to public data

The Green Paper starts by defining the stakes:

- content is the key issue to enable the development of the Information Society;
- public sector information is a premium content resource;
- barriers at European level prevent improved access to information and its better exploitation.

From there, the Green Paper defines its main objectives, bringing citizens and businesses closer to the administration, raising awareness of the wide ranging potential of data exploitation and re-engineering the public sector towards electronic government.

For citizens, easier access to information throughout Europe means more transparent administrative procedures, improved workers mobility, enhancing the reality of the single market and contributing to the European integration process. In addition, public data exploitation offers potential for new economic activities, boosting economic activity

and employment. It is important to launch European initiatives, to maintain competitiveness.
Electronic administrations should improve services to citizens and enterprises now that information society technologies enable greater interactivity, providing services for information, communication and transactions between public bodies, citizens and companies.
The Green Paper is a discussion document, it also raises many questions to consider in building an information policy. Everybody is invited to provide answers:
- What do we mean by public sector information? What categories of public sector information should be used in the debate?
- Do different conditions for access create barriers at the European level?
- How can we develop practical tools to facilitate access at the European level?
- What is the impact of different pricing policies on access and exploitation of public sector information?
- How should competition to the public sector organization be handled?
- How should the copyright on public sector information be handled?
- Right to information *versus* right of privacy: how can we strike a balance?
- How should different liability regulations affect the access to or the exploitation of public sector information?
- Is the European policy on access to and exploitation of information adequate?
- What are the priorities for action at the European level?

If we consider that GI is a significant part of public sector information, this initiative is important for the entire GI community. The information society debate has been launched in many countries, with arguments like the following: the Napoleonic law stresses that nobody can ignore the law, but many legal texts have a strong spatial component, the first being land ownership. To be compliant with such a basic legal principle, everyone should have access to this information. In addition, legal texts must change to take the emergence of the information society and providing digital data into account. The second important question is that of better assessing the impact public sector information exploitation has on economic activity, employment and the political decision to set the rules of the game for this.

GI2000

GI2000 is a communication from the Commission to the Council, to the European Parliament, to the Economic and Social Committee and to the Committee of the Regions: "Towards a European Policy Framework for Geographic Information".
GI2000 is still in an EC internal process, and has been delayed due to the Commission's resignation. It first presents the current GI market,

GI potential for society and the economy. GI2000 also recognizes the importance of GI to support EU policies: CAP, transport, ESDP, environment, etc.
The barriers to European market development are analysed, and finally, the document suggests areas for EU actions.
The first action is to provide political leadership, co-ordinating activities between all market place actors, at the European level. A High Level Working Party (HLWP) should define common goals to which everyone can subscribe, organize the debates and discussions on geographic information, stimulate co-operation and synergies between the key players, from public and private sectors.
The second action is to stimulate the development of a European Geographic Information Infrastructure. Such an infrastructure will have to provide the basic elements to enable sustainable development of the European GI market.

Why GI2000?

The GI economy

The digital information economy

There is a growing need to improve the decision-making process, and increase its efficiency. Most decisions we take have an impact on space, in one way or another. We travel, or make people travel, pollution concerns everyone, many political decisions impact our landscape and our mobility. Technology increasingly develops the information society, and GI is part of that development.
Two important questions are: Is there a digital information economy? What are the main features of the European digital information market?
The first feature is a mixed economy, with strong participation of the public sector, being an important producer, user and distributor of digital information. This participation makes the economic analysis difficult. Many questions are far from being solved today, and regulating the market makes for fiery debate.
The central questions to the debate are:
- where is the line between commercial activity and public service?
- what is the role of public service? Is access to public information free?
- does free access to public information means information for free?
- how can competition between the public and private sectors be regulated?

The European digital information market is also multicultural and multilingual, making it rich, but also complex. The scientific potential, the cultural heritage of Europe are huge, the challenge is now to build on them to succeed in reaching sustainable information market growth and in being competitive in a global context.

What is specific to the GI economy?

The information market now needs some basic infrastructure. A key issue for its development, this essentially encompasses all information and communication technologies and infrastructures. In addition, GI needs an information infrastructure to guarantee data integrity and data exchange.

In many organizations, GI is often considered as a cost, not an asset. If GI is only a necessity to run some technical tasks inside an organization, it will not try to make it pay, or use it commercially.

GI is also a horizontal activity, giving it a fragmented market with local level activity and sector specific activities. Diverse specifications, standards and reference systems make communicating and exchanging data very difficult between sectors and across administrative borders. This heterogeneity also makes it difficult to assess the market.

GI is used by many public services in the framework of their duty, contributing to improve public welfare. Although GI commercial value is unknown, its impact on the economy is considerable.

GI is used to manage assets worth billions of Euro: water, electricity, gas, telephone, streets networks and many infrastructures. It can also improve crisis management in natural hazard situations, saving lives as well as major expenditure.

Why GI2000: some practical examples

De Wit & Burrough at Utrecht University performed a very interesting exercise, analysing two major European water catchment areas. The figure shows better than words why we need more harmonisation and why we need EGII. To analyse water quality of the Rhine and Elbe river

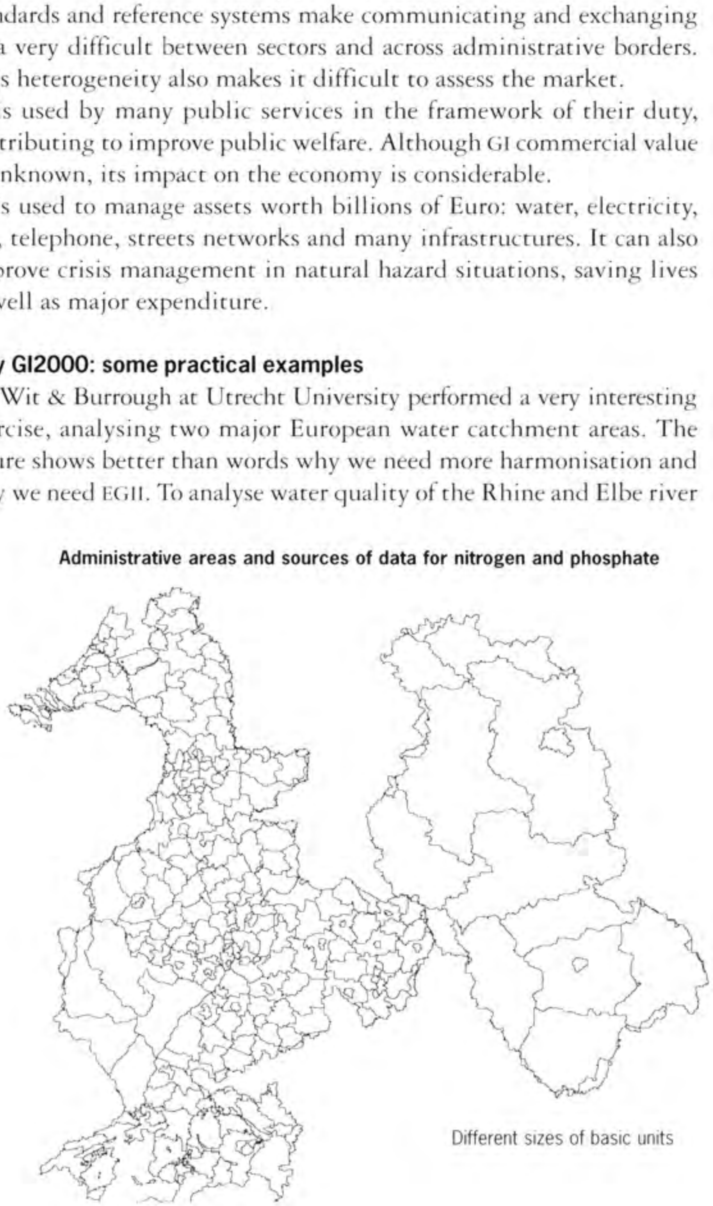


Illustration of the heterogeneity of the spatial reference for European statistics (after De Wit & Burrough).

basins, the University of Utrecht tried to exploit existing statistical data on the nitrogen and phosphate loaded in the area. All data are based on livestock and agricultural production statistics aggregated at the administrative level. The aggregation level varies from country to country, but in most cases is at municipal level. The data capture method does not consider the huge differences in the size of administrative units, causing important bias in any geographical analysis. Many political and/or economic decisions are based on such biased information. The table shows differences between various sources that should all be providing the same information. For other data, like precipitation values, change appears to follow administrative boundaries! Numerous other similar examples can help illustrate the need for better co-ordination and implementing of standards.

Some differences in official data. Examples of variation in estimation of land cover in Europe (in thousand square kilometres) (taken from RIVM 1994; De Wit & Burrough).

	1	2	3	4	5
Permanent crops					
Germany	4.42	-	1.80	2.30	5.36
France	12.11	-	12.07	12.18	31.45
Netherlands	0.29	-	0.22	0.34	1.07
UK	0.51	-	0.52	0.59	6.54
Forest					
Germany	103.84	103.84	98.56	-	100.46
France	147.84	148.10	140.675	145.81	79.63
Netherlands	3.00	3.30	1.48	3.00	0.78
UK	23.64	24.00	18.96	14.29	10.03

1: FAO-AGROSTAT. 2: Pan-European questionnaire by EUROSTAT. 3: 10 minutes pan-European land use Database.
4: Land use Statistical Database. 5: Land use Vector Database.

Achieving the social and economic potential of GI, first requires political commitment, then a defined strategy and finally, a European GI infrastructure.
The political commitment is difficult to reach, due to lack of awareness. There is no Minister responsible for GI in Europe, but it concerns many many of them in the framework of their duties: transport, environment, land planning, land registry, etc. They all need, not a theme-specific infrastructure, but a single information infrastructure that can support all GI activities.

The European Geographic information infrastructure (EGII)

It is difficult to define a European Information Infrastructure, because many conflicting ideas arise from different European GI market actors. Economic interest is an important factor as are the rapid changes to be implemented in public service organizations.

What should EGII be?

It may be too early to define in detail what should the European GI infrastructure be, but we should have at least four elements: reference data, standards, basic services and a political framework (organization).

Reference data

The table illustrates the need for harmonized reference data, to support most theme-based applications. Whatever the field, all those working at the European level will need such reference data. In many European countries, digital reference data do not cover the whole territory yet, and specifications vary from one country to another. NATO took the initiative of creating VMAP, produced for the whole of Europe following common specifications. Unfortunately, these specifications are at national level, they do not take data matching across borders into account. Moreover, there is no common data policy which remains managed by national authorities.

In the framework of the Info2000 call, the EC is funding a project called PETIT to assess the potential of creating pan-European data sets based on the VMAP product. The project is led by MEGRIN, a European association created by most of the National Mapping Agencies (NMA).

Other ideas have been forthcoming: : why not produce low cost data, with lower quality specifications, but which can meet most of the user's needs? Companies like TeleAtlas, Navtech, and mapping firms base their core business on such products.

Unless we assess the GI market better, it will be very difficult to determine the influence of data policy, price and licensing on the market. What should the public sector's role be in such a process? Do we need subsidies to make reference data available at an affordable price?

Standards

There are already many GI standards. CEN TC 287, TC 278, ISO TC 211, CEO, OGC, GILS, etc. are international GI standards, addressing part of GI needs. Unfortunately, the experience is rather negative to date, very few have implemented such standards.

Various efforts are needed to improve the situation. First it is important to raise awareness about the benefits of implementing standards, and to do this best practice experiences and pilot projects are needed. Some experiences are quite interesting: the Centre for Earth Observation (CEO) set up metadata recommendations, together with a metadata service applying them. The interest lies in the approach, trying to create a very simple standard, a kernel that can be applied by all with a reasonable amount of effort. The need for this metadata kernel, compliant with all standards, regardless of the field, was one of the main conclusions of the workshop on metadata standards held in 1997 in Santorini. A simple approach, from a simple kernel to a complete and sophisticated standard, meeting most users needs may be the first step to enable standards to be implemented and to foster their use.

Semantics is also an important and difficult issue. Europe has to manage its multilingual and multicultural characteristics. Interoperable lexicons should address that topic.

Basic services

The basic services should help develop the market but also the development of GI-related economic activity. They should make it easier to access data. Behind that concept is a major economic question: how can we fund these services? Many market surveys show that very few users are willing or ready to pay for accessing or advertising data in metadata services. European Spatial Metadata Infrastructure (ESMI) is partially funded by the EU, but is far from being a sustainable project, EEA organization, European Topic Centre/Catalogue of Data Source (ETC/CDS) and Centre for Earth Observation (CEO) are two initiatives funded by EU.
The creation of GI data repositories is a difficult task, still requiring many research and development activities. Will the market be able to find the necessary investments to build up such services? If public service funds such repositories, what will be their data policy, will they enable private sector value-adding activity?
The debate remains open for all these questions.

A political framework

Defining a long-term strategy ensuring appropriate co-ordination providing answers to questions raised above, requires political decision-making. Political decision at the European level requires a large consensus, and many consultations to reach it. GI2000 plans to create a High Level Working Party (HLWP) with the appropriate political mandate to organize consultation process, define the strategy and ensure the appropriate leadership to run the difficult process of making a European GI policy. The HLWP will also have to tackle the problem of public/private relationships, defining the rules of the game.

Some initiatives

EGII is not a one step process, the EC has taken many initiatives and some members States have already set up National GI infrastructures that will be the foundation of a European initiative.
Through the Info2000 programme, 5th Framework Programme and JRC/CEO, the EC supports many projects that add their building-block to the EGII edifice.
ESMI, CEO, the European Geological Data (GEIXS) and EEA/CDS are metadata service initiatives that received support from the Commission; MEGRIN developed a metadata server on its own to advertise the products offered by its members, the National Mapping Agencies.
Many support actions like Pan-European Links for GI (Panel-GI), GIS Interoperability Project Stimulating Interoperability in Europe (GIPSIE) have also been funded to help awareness activities and support co-ordination with Central Europe countries.

Lastly, many projects are being funded on a shared cost basis to support the creation of new products, slowly contributing to build up EGII.

The GI cross-programme line of action within the 5th Framework Programme

This line of action is still under discussion for inclusion in the IST work programme for 2000. Its aim is to develop technologies and applications that support citizen mobility, *i.e.* developing the technical foundations for mainstreaming the use of multimedia geo-information including geographic information, large-scale, heterogeneous and distributed collection of geo-spatial data and services into everyday enterprise Information Technology (IT) and mobile applications. Research will be targeted at providing generic solutions to fundamental problems recurring in most spatial and geographic information applications. Work should also cover legal and ownership issues, quality, trust and confidence in geographic data and business models, as well as the creation of a sustainable European landscape for geographic data creation, use, management and publishing, based on standards and best practice.

Marine and coastal zone geographic information: mapping the future of the United Kingdom

Victoria L. Hurrell, Frances L. Franklin, ©British Crown, 1999

The Centre for Environment, Fisheries and Aquaculture Science (CEFAS) Burnham Laboratory, Remembrance Avenue, Burnham-on-Crouch, Essex CM0 8HA, UK
v.l.hurrell@cefas.co.uk

Abstract

This paper presents an overview of the current provision for coastal and marine geographic information in the UK and looks towards how this will be carried forward into the next millennium. It draws on the findings of a recent workshop hosted by CEFAS entitled 'Integrated mapping of the UK marine and coastal zone - the way forward'.
The key findings of this workshop were that within coastal and marine mapping there are clear requirements for a concerted approach, better access to information, establishing core data sets, identifying research needs and taking action. Some of these criteria have already been addressed by existing projects. However, there is still a clear need for a proactive approach in order to fulfil the conclusions of the workshop. These conclusions consolidate many of the findings of prior reports such as the EU Demonstration Programme on Integrated Management in Coastal Zones and the UK's Greenwich Project.

Résumé

Ce document est une présentation générale des dispositions actuelles concernant les informations géographiques côtières et maritimes au Royaume-Uni, et il étudie comment ces dispositions seront prises en compte au cours du prochain millénaire. Il est basé sur les constatations faites lors d'un atelier qui s'est tenu récemment au CEFAS, intitulé « Integrated mapping of the UK marine and coastal zone - the way forward ».
Les constatations majeures de cet atelier ont été que, pour l'établissement des cartes des zones côtières et maritimes, on a manifestement besoin d'adopter une approche concertée, de jouir d'un meilleur accès aux informations, d'établir des ensembles de données clés, d'identifier les besoins au niveau de la recherche, et d'agir. Certains de ces critères ont déjà été abordés par des projets existants. Néanmoins, il est de toute évidence nécessaire d'adopter une approche proactive pour réaliser les conclusions de l'atelier.

Dans ces conclusions, on retrouve un grand nombre des constatations figurant dans des rapports antérieurs comme le programme de démonstration de l'Union européenne sur la gestion intégrée dans les zones côtières (ICZM) et le projet Greenwich.

Introduction

The importance of the marine and coastal zone as a valuable resource should not be underestimated. This is particularly true for the United Kingdom, which, as an island nation, relies heavily on its coasts and seas for both social and economic well being. It is the focus for a considerable amount of activity by a diverse range of users who impact not only on the environment but also on each other. It is, therefore, vitally important that it be managed in an effective and integrated fashion. The most important component in order to achieve this is appropriate and timely information on which to base management decisions. Without this, the UK's ability to ensure sustainable development, to protect the environment, and ultimately maintain its role as a trading nation will be impaired.

The need for change was identified by a recent workshop entitled 'Integrated mapping of the UK marine and coastal zone - the way forward'. This aimed to explore what actions are required to ensure that users of marine and coastal geographic information have access to the information needed in order to fulfil their responsibilities effectively. The workshop was hosted by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) at their Lowestoft laboratory in June 1999. As an Executive Agency of the UK Government's Ministry of Agriculture, Fisheries and Food (MAFF), CEFAS provides advice on fisheries management and environmental protection, and undertakes appropriate research in these areas. It is, therefore, both a user and producer of marine and coastal zone data, and well placed to play a role in directing the future of coastal and marine mapping in the UK. Further information can be found at the CEFAS Website at *http://www.cefas.co.uk*. A report of the findings of the workshop is available from CEFAS (Franklin & Hurrell, 1999).

The workshop identified key issues that were felt to be inhibiting the provision of coastal and marine geographic information to those who need it. In particular, ease of access to suitable information emerged as a widespread problem which is of fundamental importance, and various recommendations were made as to how this could be tackled. The issues raised and the conclusions from the workshop are addressed in greater detail as part of this paper.

One of the objectives of the workshop was to review the current provision for marine and coastal zone geographic information within the UK by giving a brief outline of existing projects. The following is not an exhaustive summary of these projects; rather it aims to give an overview of projects that have been established on a national scale and have had a widespread impact on the coastal and marine information community.

Review of current marine and coastal zone mapping projects in the UK

UKDMAP

The United Kingdom Digital Marine Atlas Project (UKDMAP) was created in 1985 as a digital successor to the printed 'Atlas of the Seas around Britain' (Lee & Ramster, 1981). It was developed and published by the British Oceanographic Data Centre (BODC).

The aims of the project were twofold. Firstly, to provide wide-ranging and easily updateable reference works on the marine environment around the UK, of use to the scientific, educational and commercial sectors. Secondly, to provide a 'shop window' through which users may more readily determine the availability of data and/or expertise on a given subject, and data suppliers can ensure that more effective use is made of valuable data sets.

The third edition (for Windows 95/98/NT) was released in July 1998, and is available on disk or CD-ROM. The display allows the user to pan, zoom, overlay, print and query the data. The coverage is comprehensive with over 1 600 thematic charts relating to the seas and coasts around the British Isles, each with descriptive text attached that identifies the source of the data.

The UKDMAP was not designed as a data analysis system, Geographic Information System (GIS) or cartographic package, and consequently does not allow data to be downloaded and integrated into the user's software. However, it does provide a useful overview of existing data, essentially establishing a 'digital catalogue' of coastal and marine data sets.

Further information, including a content list, is available from *http://www.nbi.ac.uk/bodc/ukdmapv3.html*.

Marine Environmental Data Co-ordinator and Network

An Inter Agency Committee on Marine Science and Technology (IACMST) Working Group recommended that a mechanism be established to facilitate regular communication between marine environmental data managers and providers. This recognized the fact that marine environmental data are widely distributed throughout the UK amongst government departments, laboratories, universities and commercial organizations.

This led to the instigation of a Marine Environmental Data (MED) Co-ordinator who works with participating departments to provide an enhanced system of networking amongst users and providers of marine environmental data. The British Oceanographic Data Centre (BODC) currently supplies this post. The responsibilities of the MED Co-ordinator are to develop data management policies, establish mechanisms to facilitate data exchange, raise the visibility of MED activities, and to develop and maintain inventories of data.

This last objective includes the maintenance of the UK Marine Environmental Data Network (UKMED) which aims to establish an inventory of all available UK sources of marine environmental data and their holdings. Further details can be found at the MED homepage at *http://www.pol.ac.uk/bodc/ukmed.html*.

The Directory forms part of the European Directory of Marine Environmental Data (EDMED) which is a collaborative venture within the EU MAST programme and is available as a searchable directory on the Internet at *http://www.pol.ac.uk/bodc/edmed*.

Coastal and Regional Seas Directories

The Coastal Directories Project began as a result of a suggestion made by UK representatives at the second meeting of the North Sea Task Force in 1989. They felt that information on coastal habitats and species of conservation importance should be included in the Quality Status Report (QSR) then being produced. The principal aim was to produce a comprehensive description of the North Sea coastal margin of the UK, including its habitats, species and human activities.

This was initially published as The Directory of the North Seas Coastal Margin and evolved into 16 volumes, covering 17 regions. These collate existing information on the United Kingdom and Isle of Man coastal zone to provide national and regional overviews of the natural resources and human activities. A key feature of the Directories is the system of indexes pointing to more detailed sources of information.

One of the key lessons learnt from the Coastal Directories approach has been that adopting a participatory approach in the data gathering process is as relevant and important at the national level as it is at more local scales. Participation promotes better understanding and acceptance of management choices: a vital element in achieving greater integration of coastal management.

As the publication cycle drew to a close, the Project steering group commissioned a study to look at the options for further development of the Project's work. They chose to develop the Directories into a software application. Funding was secured from the United Kingdom Offshore Operators Association (UKOOA) to develop the first phase of the Coastal Directories Electronic Platform (CDEP). This software provides a map-based interface with the coastal directories through which dot maps, contextual data, and the full text of the directories can be accessed.

The Land Ocean Interaction Study

The Land Ocean Interaction Study (LOIS) is an eight year, £30 m research project funded by the Natural Environment Research Council (NERC) and involves over 300 scientists. As such it is the largest NERC funded research programme. It has, consequently, produced vast amounts of commercially available data relating to each of the LOIS topic areas: BIOTA (the biological component), Shelf Edge Study (SES, the marine component), Land Ocean Evolution Perspective Study (LOEPS, the geological component) and Rivers, Atmosphere and Coasts Study (RACS). Further details can be found at *http://www.pml.ac.uk/lois/index.html*.

The temporal component of data is equally as important as the geographical component; this is especially true in the coastal zone. LOIS has attempted to convey this with its time series data consisting of several image sequences comprising hundreds of data sets. Specialist software was developed for the project in order to effectively deal with this component of the data, and the result was the Spatio-Temporal Environmental Manager (STEM) which is a 4-dimensional GIS data viewer.

Association of Geographic Information Special Interest Group (AGI SIG) on Marine and Coastal Zone Management

The purpose of the SIG, which was founded in 1995, is to provide a UK forum to cater for the growing interest in marine and coastal applications of GIS and related technologies. The objectives of the Group are primarily to increase awareness of developments and innovations in GIS and related technologies for use in marine and coastal zone environments and to provide a means of co-ordination for future developments (*e.g.* by defining data standards, data transfer formats, data analysis techniques). The Group also aims to provide a central repository for information and a point of contact for organizations both within the UK and internationally who have queries regarding GIS applications to the marine and coastal zone environments. It disseminates news, information and research *via* its World Wide Web page (*http://www.agi.org.uk/pages/structure/committees/sigs/mczm.html*), seminars and workshop sessions held at the annual AGI conference.

MAFF Marine and Coastal Zone Mapping Project

This project was initiated in April 1999 by CEFAS as a scoping study, to explore the opportunities for furthering the use of geographic information as a tool for marine and coastal zone management. The aims of the project were to maximise the use of geographic information held within the organization, to forge links with mapping projects being carried out by other organizations, and to help determine the future direction of marine and coastal zone mapping in the UK. This latter objective was largely fulfilled within a workshop hosted by CEFAS in June 1999 entitled 'Integrated mapping of the UK marine and coastal zone - the way forward'.

The CEFAS mapping workshop

Aims

The aim of the workshop was to explore what action needed to be taken so that users of marine and coastal zone geographic information have access to what they need in order to fulfil their responsibilities effectively. It was intended that future applications to UK government departments (MAFF and the Department of the Environment, Transport and Regions) for funding relating to marine and coastal zone mapping projects would be required to demonstrate that they contribute to the needs identified by the workshop. There are five key issues that arose as a result.

Key issues

Improving access to data and information

The need for better access to data and information is especially important in the UK as marine and coastal data are widely distributed amongst a variety of organizations and the users of data are widely dispersed across the country. The issue of access to appropriate data can be split into three areas.

Awareness of available data

Because so many different organizations are involved in generating marine and coastal zone information it is often difficult to establish what data are held and by whom. There may be a perception of a lack of data, where in fact data do already exist. This lack of awareness calls for more effective use of metadata, *i.e.* information about data. A protocol needs to be developed whereby data owners have responsibility for attaching metadata as standard procedure. A central metadata directory could subsequently be provided which would be accessed *via* an Internet gateway, for example.

Availability

A further barrier is the lack of availability of some types of data; once users are aware of which data exist, they need to be able to access it. The most pertinent issue in the UK appears to be obtaining data from publicly funded bodies, such as the Ordnance Survey and the UK Hydrographic Office. Because the data from such organizations is expected to generate significant revenue, it is consequently only available at a high, and often unrealistic, cost to users. Alternatively, data may not be widely available as they are viewed as commercially sensitive, as is the case with much privately held fisheries data in the UK.

The way forward, therefore, lies in promoting better access to data held by public and commercial organizations by:

- using the Internet to provide pathways to information;
- providing cheaper and more timely access to publicly funded data;
- promoting a culture change within organizations to encourage them to allow access to commercial information;
- resolving issues relating to ownership/licensing/confidentiality/copyright;
- developing strategic rules for data provision and archiving.

Fit for purpose

Once users are aware of the data available to them, the final requirement is that it is fit for the purpose for which it is needed. Data lose potential value if not recorded in an easily re-useable format. There may be a lack of compatibility, for example, between the quality control or sampling procedures used for different projects. In addition, different users will have different requirements for scale and currency of data. The introduction of standard guidelines would contribute greatly to a more integrated approach, and could extend to recommendations for standard data types and software.

Core data sets

Despite the complex and varied needs of users of marine and coastal zone geographic information, there is a strong consensus of opinion on the need for accurate and reliable base maps. This is obviously of fundamental importance. Publicly funded base data should be made more readily accessible by becoming low cost and being available from a central source. There also needs to be integration between land-based and marine maps, which would be suitable for coastal zone use. The present situation is not at all satisfactory, with a choice between terrestrial or hydrographic base maps that are not readily compatible.

The UK Government should be encouraged to adopt a strong policy regarding provision of base data sets at a reasonable cost, particularly those produced by the Ordnance Survey (OS) and the UK Hydrographic Office (UKHO). These should include high and low water marks and key information relating to the seabed and the water column, coastal habitats and adjacent land. The 1993 prototype 1:25 000 map of The Solent is an excellent model (Ordnance Survey & UK Hydrographic Office, 1993), which was unfortunately discontinued at the time due to a perceived lack of demand.

Research needs

A framework needs to be developed within which research takes place in order to co-ordinate efforts and to place projects in their wider context. This would allow researchers to more easily define the questions which research needs to answer and avoid duplication of effort. This framework should also facilitate input from end users in setting research agendas.

Co-ordinating mechanism

The users of marine and coastal data need to take a concerted approach to raise the political profile of marine and coastal zone mapping, in order to bring about necessary changes. A permanent, nation-wide mechanism to provide proactive leadership and co-ordination may be a good way to do this. It was suggested either that a new centre should be established, or that we make use of an existing body such as the Inter Agency Committee for Marine Science and Technology's (IACMST) Marine Environment Data Action Group. In whatever form it was established, it would be vital that such a body should be cross-sectoral, with representatives of all stakeholder groups both from within and outside Government.

Action

The final, and probably most important issue, is that there has been enough discussion, and it is time to take action!

Are these issues being addressed?

Access to data

The provision for access to data and information is beginning to be tackled at both a regional and national levels. Building networking initiatives is an effective way of promoting the flow of information and utilising the appropriate knowledge base.

On a national scale, the National Biodiversity Network (NBN) is a new networking initiative that was set up in April 1999, and aims to establish an electronic network of linked wildlife databases across the UK. It addresses many of the data access issues raised during the workshop by relying on:

- the formation of partnerships between users and producers of information, with mutual input from both parties to aid co-operation and agreement;
- data ownership remaining with local and national custodians who will be responsible for managing databases within the partnerships. This will help provide a local and national context within which to view the data;
- developing a framework of standards and best practice guidelines, with input from both users and producers of data.

This last point is important for a number of reasons, for example to facilitate information exchange. It will also establish data collection guidelines so that data can realise their full potential, and not be bound by use only within a specific project. In addition, it will help to address copyright issues, which are especially important when dealing with sensitive data, *e.g.* breeding sites of rare species. Further information is available from *http://www.nbn.org.uk*.

On a regional scale, the promotion of 'Smart communities' has illustrated how this can be done. Brian Shipman (Cornwall County Council) defines a 'Smart community' as one "in which specialist scientific knowledge and local understanding of coastal systems can exist side by side, and inform each other" (Heeps & Willis, 1999). This 'grass roots' involvement is vital if networks are to be successful on a regional or national scale. This theme also emerged strongly from the Info-Coast'99 symposium (1999).

The Cornwall Coastline Environment Research Forum is an example of an initiative which was set up to promote the benefits of 'Smart communities' by developing communication between scientists, managers and the local community. Similar Forums have been initiated elsewhere across the UK although, as yet, not widely.

A recent report, produced by Construction Industry Research and Information Association (CIRIA) earlier this year, also contributes to addressing the problems of data accessibility and compatibility for data exchange. The MUSEC report - 'Maximising the Use and Exchange of Coastal data - a guide to good practice' (Millard & Sayers, 1999) has the following objectives:

- to produce guidance and recommendations for organizations who undertake coastal monitoring and coastal data collection on the consis-

tency of data mechanisms for data exchange between organizations;
- to encourage the concept of the common brokerage of coastal data to facilitate data sharing within sectoral groups and between organizations;
- to improve understanding of the mechanisms and issues that effect data use and exchange;
- to improve awareness of data types and availability.

Core data sets

Ordnance Survey, the UK's national mapping agency, has recently signed a common purchasing framework agreement with nine government departments including the British Geological Survey (BGS), English Nature (EN), Environment Agency (EA) and the Ministry for Agriculture, Fisheries and Food (MAFF). This is a step in the right direction towards the provision of more readily available base data sets, and in keeping with the UK Governments commitment to promoting its 'joined-up' Government Initiative.

A co-ordinating mechanism?

The Greenwich Project (Office of Science and Technology, 1999) evolved from the UK Government's Marine Foresight Programme and aims to set up a series of working groups with the following objectives:
- to establish an operational forecast centre and research programme;
- to secure funding to promote co-operation between industry and academia;
- to improve the supply of graduate and other Higher Education recruits;
- to improve the availability of publicly funded data.

The project is due to be officially launched in January 2000, and is currently seeking involvement from the key Government Agencies involved in marine science, in addition to other Government Agencies.

Conclusions

Planners and managers need access to comprehensive, current and accurate information in order to make robust decisions concerning the marine and coastal zone environment. The CEFAS workshop identified a lack of awareness and a lack of availability of appropriate data and information, which threaten to inhibit effective coastal zone management. This needs to be tackled simultaneously from a number of different perspectives if improvements are to be made.

The role of technology is becoming increasingly important as a means of combating these data access issues, in particular the use of Web technologies (whether intranet or Internet). In addition, GIS is becoming an increasingly prominent part of the IT (Information Technology) industry, which is reflected by the fact that mainstream IT players such as Microsoft and Oracle are becoming actively involved in the GIS market-place. This promises to promote the development of GIS technologies, allowing increasing functionality not only on the desktop, but also over the Web. The coastal and marine community as a whole must ensure that they are in a position to take full advantage of the potential of the Internet as technology advances, by ensuring an integrated and forward looking approach.

The workshop identified a clear need for change if the UK is not to fall behind other countries and jeopardise its role as a trading nation. However, considerable effort has already been invested in addressing many of the issues that arose as a result of the workshop. There are a number of recent projects which have proven successful, or provided lessons that can be learnt, a handful of which have been mentioned in this paper. It is important to build on the successes of these initiatives, and consider best practice models from both within the UK and worldwide.

It is encouraging that many of these recommendations confirmed those identified by national initiatives such as the Greenwich Project, as well as on a European scale, for example by the EU Demonstration Programme's Study on Integrated Management in Coastal Zones (Doody *et al.*, 1998) and by the Info-Coast'99 Symposium. The next step is to ensure that we begin to address these issues in an integrated, co-ordinated and proactive manner.

Bibliogaphic references

Doody J.P., Pamplin C.F., Gilbert C., Bridge L.,1998. European Union Demonstration Programme on Integrated Management in Coastal Zones, Thematic Study F - Information required for integrated coastal zone management. Report to the European Environment Agency, Copenhagen, Denmark.

Franklin F.L., Hurrell V.L. (Comp.), 1999. Integrated mapping of the UK marine and coastal zone - the way forward. Report of a MAFF-sponsored workshop held at CEFAS Lowestoft Laboratory on June 1999. CEFAS Lowestoft, 56 p.

Heeps C., Willis A. (eds), 1999. CoastNet. The Bulletin of the Coastal Heritage Network, 4(1), p. 8, Spring.

Info-Coast'99. Report of the 1st European Symposium on Knowledge and Information Management for the Coastal Zone, The Netherlands.

Lee A.J., Ramster J.W. (Comp.), 1981. Atlas of the Sea around the British Isles. MAFF London, 75 maps (unpaginated).

Millard K., Sayers P., 1999. Maximising the Use and Exchange of Coastal Data - a guide to best practice. Construction Industry Research and Information Association (CIRIA), Research Project RP584, Draft, June.

Ordnance Survey and United Kingdom Hydrographic Office, 1993. Langstone Harbour to Pagham Harbour, The Solent - Sheet 4. 1:25 000 Prototype map.

OST (Office of Science and Technology), 1999. The Greenwich Project - A Strategy for the Development of the Nation's Marine Information Industry. Dep. Trade and Industry, London.

Chapitre 1

System design and organization, access to data

Conception et organisation des systèmes, accès aux données

Données géographiques de référence en domaine littoral

Serge Allain[1], Brigitte Guillaumont[2], Christophe Le Visage[1], Lionel Loubersac[2], Jacques Populus[2]

(1) Epshom, 13 rue du Chatellier, BP 426, 29275 Brest, France - allain@shom.fr

(2) Ifremer, Del/ao, BP 70, 29280 Plouzané, France

Résumé

Devant la demande croissante des aménageurs du territoire, des scientifiques ou des usagers travaillant en milieu littoral, le Shom et l'Ifremer ont mis en commun au sein d'un groupe de travail les moyens qu'ils consacrent à l'identification et la définition des « données géographiques de référence » en domaine littoral. Ce travail d'analyse est conduit à travers une démarche pragmatique croisée entre une approche par thème et une approche par application. Une grille de lecture a été construite, prenant en compte un certain nombre de paramètres tels que vocabulaire, données existantes, intérêt applicatif, cohérence et forme des produits. Cet article examine des extraits relatifs aux thèmes bathymétrie, limites physiographiques, hydrodynamique côtière, limites et zones administratives. L'utilisation pratique des données géographiques est illustrée par deux applications : pêche côtière au chalut et gestion d'une zone conchylicole.

En conclusion, il est proposé de créer un groupe « mer » au sein du Conseil national de l'information géographique (Cnig), de lui confier la diffusion du rapport du groupe de travail ainsi que la promotion de la mise en œuvre de données de référence sur les espaces côtiers.

Abstract

In order to meet the increasing demand for maps and geographic data from the coastal zone community (managers, local authorities, scientists, other potential users), Shom and Ifremer have set up a specific working group. Its mandate is to identify and analyse what is referred to as coastal "geographic reference data". The analysis has been conducted using a practical crossed approach between the geographical data themes on one hand and the various applications and their needs on the other. An analysis template has been devised, through which all data sets are examined. It contains a number of parameters such as vocabulary, existing data, focus of application, consistence and form of the data. The rationale is illustrated by extracts concerning the themes of bathymetry, physiographic boundaries, coastal hydrodynamics and regulatory zones and boundaries. The practical use of reference data sets is illustrated by two examples : a case of coastal trawler fisheries and the management

of a shellfish culture area. The article concludes by calling for the creation of a specific "Coastal" group within Cnig (Conseil national de l'information géographique), which could make the present report public and foster the advent of reference data for the coastal zone.

Introduction

Le Shom et l'Ifremer sont, en raison de leurs missions propres, collecteurs, détenteurs, gestionnaires et utilisateurs de nombre de données géoréférencées sur la zone littorale française. Devant la demande croissante des aménageurs du territoire, des scientifiques ou des usagers travaillant en milieu littoral, les deux organismes, du fait de leur complémentarité, ont mis en commun au sein d'un groupe de travail les moyens qu'ils consacrent à l'identification et à la définition des données de référence en domaine littoral. Les objectifs du groupe sont d'analyser les besoins, d'inventorier les thèmes et objets géographiques de référence, d'identifier les sources de données et de proposer des solutions pour leur mise à disposition répondant à des demandes d'aujourd'hui comme en anticipation des besoins futurs.

Selon les recommandations du Conseil national de l'information géographique (Cnig), les données de référence sont définies comme « l'ensemble des informations permettant à chaque utilisateur particulier d'associer des données de différentes origines et de positionner dans l'espace ses informations propres. Ces données ne répondent à aucun besoin applicatif particulier mais doivent, au contraire, être communes au maximum d'applications de façon à permettre la manipulation et la combinaison des informations de toutes origines qui leur seront rattachées » (Cnig, 1998).

Analyse et réflexions

Méthode de travail

Le lien direct entre applications et données de référence n'est pas implicite. En effet, la démarche classique des utilisateurs consiste plutôt à exploiter les données disponibles qu'à imaginer celles dont il serait souhaitable de disposer.

Une démarche pragmatique a été utilisée. Elle comprend deux étapes :

- une approche par thème et données géographiques habituellement organisés au sein de bases ou mis à disposition sous forme de cartes ;
- une approche par application listant les thèmes nécessaires. Cette approche se fonde sur les besoins couverts traditionnellement (par exemple la navigation), sur les besoins nouveaux qui s'expriment auprès du Shom ou émis à la suite de travaux de groupes thématiques internes à l'Ifremer, ainsi que sur l'analyse des informations figurant (ou suggérées) dans les études préalables à la définition des Schémas de mise en valeur de la mer (SMVM) et des Contrats de baie (Collectif, 1993 ; Troadec & Le Goff, 1997).

L'analyse croisée entre les deux approches permet de dégager les informations de référence structurantes communes à plusieurs applications. Par transitivité apparaissent les liens entre applications et données de référence.

On appelle thème une famille de paramètres physiques ou d'entités de même nature. Chacun des thèmes a fait l'objet d'une fiche suivant une grille d'analyse type prenant en considération un certain nombre de critères. Les thèmes ont été regroupés en cinq centres d'intérêt :

- géographie maritime : limites physiographiques, bathymétrie et géologie-sédimentologie ;
- faune et flore : domaines pélagique et benthique ;
- hydrodynamique, apports et caractéristiques des masses d'eau ;
- activités humaines et usages : amers et balisage, objets sous-marins, infrastructures des ports et mouillages, cultures marines, pêche professionnelle, pêche de loisirs, extraction des ressources minérales, activités récréatives ;
- administration et réglementation : entités physiographiques normalisées, limites et zonages administratifs, réglementaires et techniques.

Comme il n'est pas possible de décrire ici l'ensemble des données numériques de référence envisageables telles quelles seront déduites de l'analyse du groupe de travail, on se limitera à illustrer la démarche par des extraits de l'analyse thématique faite pour la bathymétrie, complétés par quelques produits envisagés pour trois autres thèmes.

Grille d'analyse et illustration par le thème bathymétrie

Le vocabulaire

Le vocabulaire spécifique de chaque thème a été défini en préambule de l'analyse (voir tableau). Cette étape indispensable a permis de lever les ambiguïtés et de parler un langage commun (Commission européenne, 1999). Il a été fait un bilan des dictionnaires existants afin de compléter, d'améliorer et de proposer le cas échéant des définitions des termes utilisés.

Vocabulaire relatif à la bathymétrie.

Vocabulaire	Définition	Dictionnaire
Profondeur	Hauteur verticale au-dessus du fond du niveau instantané de la mer.	OHI
Bathymétrie	Description de la profondeur de l'océan par rapport à un niveau de référence donné (zéro hydrographique).	OHI OHI + Shom
Isobathe	Courbe de niveau bathymétrique. Les isobathes sont les intersections de la surface représentant le fond de la mer avec des surfaces de profondeur constante. Ces isobathes sont distinctes des lignes de niveaux sécurisées portées sur les cartes marines (isobathes cartographiques).	
Isohypse	Courbe de niveau terrestre. Les isohypses sont les intersections de la surface représentant la terre avec des surfaces d'altitude constante.	
Sonde	Hauteur verticale au-dessus du fond du niveau de référence conventionnel (zéro hydrographique ou zéro des sondes).	OHI
MNT-Modèle numérique de terrain	Ensemble de valeurs de paramètres données aux nœuds de grilles régulières. Le pas de la grille (qui peut être différent suivant les deux directions) peut être régulier en projection ou en coordonnées géographiques.	Shom
Semis de sondes	Semis irréguliers de sondes rédigés à partir de données élaborées archivées par profil de sonde à la densité requise en hydrographie (échantillonnage longitudinal plus dense que l'échantillonnage transversal).	Shom
Zéro hydrographique	Niveau de référence commun aux cartes marines et aux annuaires de marée. C'est aussi le début des eaux territoriales. En France, le zéro hydrographique est théoriquement le niveau de basse mer astronomique extrême, synonyme de zéro des cartes. En pratique, le zéro hydrographique est approximativement le niveau des basses mers astronomiques (ou LAT).	OHI
Trait de côte	Limite conventionnelle du domaine maritime au voisinage de la laisse de pleine mer pour les côtes de France, Atlantique et Manche. Le long des côtes méditerranéennes, le trait de côte est défini comme le niveau maximal hivernal.	OHI + Shom
Généralisation	Simplification d'une information géographique pour tenir compte de l'échelle de la représentation. La généralisation peut entraîner la suppression d'informations secondaires, ou la simplification de la représentation (lissage de courbe…).	OHI

Données existantes

Un inventaire systématique des données déjà produites et archivées dans le thème considéré a été réalisé. Ce travail de récolement de l'information a permis de renseigner divers champs d'informations permettant de juger du suivi des données et de leur pérennisation. Les critères retenus concernent :

- source, extension spatiale et temporelle des données ;
- unités de mesure, systèmes géodésiques et niveaux verticaux ;
- forme de l'information et mise à jour ;
- modes d'acquisition actuels ou futurs de ces informations.

Dans le cas du thème bathymétrie, l'analyse est la suivante :

• Source, extension spatiale et temporelle des données

Les producteurs sont le Shom, les services maritimes des DDE, l'Ifremer, l'IFRTP, les ports autonomes, les universités, le CNRS, l'EDF... Le gestionnaire est le Shom, responsable de la gestion de la « banque nationale de données bathymétriques ». Les données peuvent concerner tout le domaine maritime, des grands fonds (mer territoriale, ZEE, plateau continental) jusqu'à la laisse de pleine mer de vive-eau. Le recouvrement temporel souhaité dépend de l'estimation de l'évolution de la zone et de son intérêt : ce recouvrement peut être mensuel (zones portuaires), semestriel pour les zones à forte évolution (embouchure de fleuve) ou encore séculaire. En outre, l'IGN produit l'isohypse zéro et un MNT à maille de 50 m au-dessus de cette référence.

• Unités de mesure, systèmes géodésiques et niveaux verticaux

L'unité physique employée en référence verticale est le mètre. Les niveaux verticaux de référence sont soit le zéro hydrographique, soit le zéro de nivellement terrestre. Les systèmes géodésiques de référence sont, au large, le système global type ITRF ou WGS 84, sur le proche littoral le système NTF ou RGF93 ou encore les densifications locales ou régionales de l'ITRF.

• Forme de l'information et mise à jour

Les données peuvent être exprimées sous forme de sondes provenant de levés bathymétriques. Elles sont alors archivées en base de données pour être mise à disposition d'un SIG. Elles couvrent 95 % des côtes métropolitaines au 1/10 000 ou plus grandes échelles, 100 % au 1/25 000 ou plus grandes échelles. Elles peuvent provenir de cartes marines, ce sont alors des sondes « cartographiques », c'est-à-dire un choix de semis de sondes sécurisés destinés à l'usage de la cartographie marine (choix des têtes de fond susceptibles de constituer un danger pour la navigation de surface).

Les données peuvent être aussi exprimées sous forme d'isobathes qui sont générées à partir de la base de données bathymétriques (à l'échelle originale du levé ou à une échelle dérivée et à différents niveaux de généralisation). Elles sont exprimées en mètres aux valeurs rondes. Les isobathes sont négatives sur l'estran et positives sur les zones couvertes. Ces « isobathes cartographiques » correspondent à des lignes d'iso-valeurs sécurisées pour la navigation. Elles sont généralisées en fonction de l'échelle de représentation.

Les données peuvent enfin être exprimées sous forme de modèles numériques de terrain côtiers (MNT) (en cours de définition, outil disponible au Shom à la fin 1999).

Les mailles seront de 10, 20, 50 ou 100 m, 0,05', 1 km, 0,5'.

Nota : les isobathes peuvent aussi être générées à partir de MNT, dans ce cas, ce sont des « isobathes réelles ».

• Modes d'acquisition actuels ou futurs de ces informations

En bathymétrie, l'acquisition se fait par des campagnes en bateau (sondeur vertical ou sondeur multifaisceaux), par du traitement de l'imagerie Spot ou Radar (ERS1) pour des zones à faible bathymétrie et en eau non turbide et par photogrammétrie sur l'estran. Le laser aéroporté pour les levés sur la zone d'estran est d'ores et déjà un mode d'acquisition utilisé dans de nombreux pays.

Intérêt applicatif

L'inventaire non-exhaustif des besoins connus et/ou pressentis et de la forme des produits souhaités permet de juger du caractère de référence des données du thème. Ainsi, certaines informations « mono-usage » ne sont pas de référence pour l'ensemble, même si elles restent indispensables à un ou deux usages particuliers. Ce travail a préparé les ponts entre fiches thématiques et fiches « applications ».
Les produits bathymétriques numériques sont destinés à satisfaire les besoins suivants (on ne reprend pas ici le détail des produits souhaités par application) :

- description générale et représentation graphique simplifiée de la structure des fonds marins (cartes classiques et électroniques, systèmes d'aide à la décision), description de l'interface terre-mer, lien entre les topographies marine et terrestre ;
- sécurité de la navigation en surface, de la navigation sous-marine ou de la mise en œuvre d'engins sous-marins ;
- exploitation halieutique ;
- pêche sous-marine professionnelle et de loisirs ;
- topographie de l'estran : opération de plageage, opérations amphibies, occupation du domaine public maritime (DPM) ;
- présélection de sites ;
- modélisation numérique hydrodynamique et sédimentologique, études géomorphologiques ou écologiques ;
- support pédagogique ou ludique.

Cohérence et forme envisagée pour les produits

Les informations existantes ou souhaitées pour les diverses applications listées ci-dessus doivent être cohérentes avec les autres entités du thème concerné mais également avec les autres thèmes.
Deux niveaux de référence ont été définis :
- les informations dites de niveau 1, structurantes et indispensables à un large ensemble d'applications ;
- les informations dites de niveau 2, plus finalisées et s'appuyant sur des données de niveau 1.

Pour chaque entité, il s'agit de spécifier les données par leur forme, leur échelle de représentation, leur couverture complète ou partielle le long des côtes de France, leur densité d'information, leur système géodésique de représentation.
Dans le cas de la bathymétrie, la cohérence doit être assurée entre isobathes et semis de sondes, entre isobathes et MNT, entre MNT à différentes échelles ainsi qu'entre isobathes et lignes physiographiques.

Les produits de référence proposés sont les suivants :
* ***Niveau 1 :*** *Modèle numérique de terrain*
Densité d'information : entre l'isohypse +5 m et l'isobathe 20 m, maillage souhaité de 10 m ; entre l'isobathe 20 m et l'isobathe 50 m, maillage de 50 m ; au-delà de 50 m, maillage de 100 mètres. Informations localisées en X, Y dans le système RGF93, projection Lambert 93, profondeur référencée par rapport au zéro hydrographique, cote référencée par rapport au zéro de nivellement terrestre. La précision en Z souhaitée sur l'estran doit être supérieure à 20 centimètres.
* ***Niveau 1 :*** *Isohypse (référence verticale : zéro de nivellement terrestre)*
Entre l'isohypse +5 m et le zéro hydrographique, courbes de niveau données tous les mètres, échelles de représentation au 1/10 000 et au 1/25 000, densité d'information de 1 mm à l'échelle de représentation et système géodésique RGF93.
* ***Niveau 1 :*** *Isobathe (référence verticale : zéro hydrographique)*
Échelle de représentation : entre le trait de côte et l'isobathe 20 m, isobathes tous les mètres au 1/10 000, généralisées au 1/25 000 ; entre 20 m et 50 m, isobathes tous les 5 m au 1/50 000 ; au-delà de 50 m, isobathes tous les 10 m au 1/100 000 ; densité de points de 1 mm à l'échelle de représentation ; système géodésique RGF93.
Nota : ces isobathes sont distinctes des lignes de niveaux sécurisées portées sur les cartes marines (isobathes cartographiques).

Commentaire particulier
Un champ de commentaires particulier à chacun des thèmes a permis, lorsqu'il y avait lieu, de préciser des éléments que l'on ne pouvait décrire dans les autres champs.

Autres exemples de thèmes et produits envisagés
Dans ce qui suit, on se limite à trois cas, en indiquant les intérêts applicatifs principaux et les produits prioritaires envisageables.

Les limites physiographiques
Les informations sur les limites physiographiques sont destinées à satisfaire les besoins suivants :
- continuité de la cartographie terrestre (IGN) et de la cartographie marine (Shom), limites du DPM naturel ;
- définition et suivi du trait de côte ; vulnérabilité et sensibilité, protection du littoral (calcul des états limites des ouvrages maritimes en génie côtier) ;
- modélisation prévisionnelle d'arrivée des niveaux extrêmes et zones de submersion (sécurité civile, études d'impact) ;
- étude de l'évolution du niveau moyen des océans (climatologie) ;
- aménagement du littoral, applications aquacoles, tourisme…

Les données numériques de référence ressortissant à ce thème sont les suivantes :
* ***Niveau** 1 : Zéro hydrographique : ligne continue à couverture nationale*
Échelle de représentation au 1/10 000, généralisée successivement aux 1/25 000, 1/50 000 et 1/100 000.
* ***Niveau** 1 : Trait de côte : ligne continue à couverture nationale et prolongée dans les estuaires*
Échelle de représentation au 1/25 000, généralisée aux 1/50 000, 1/100 000, 1/250 000 et 1/1 000 000 ; couverture à grande échelle selon les zones évolutives aux 1/10 000 et 1/5 000, couverture complète au 1/10 000 souhaitée à terme.
* ***Niveau** 2 : Niveaux extrêmes de pleine mer (PM) et de basse mer (BM)* (Simon, 1994b)
Un premier produit existe déjà : il s'agit des informations statistiques ponctuelles (aux points d'observation) des côtes de France, Manche et Atlantique, avec à terme une couverture en Méditerranée aux périodes de retour de 5, 10, 25, 50 et 100 ans.
Un deuxième produit reste à créer. Il concerne la cartographie des zones inondables ou à risque, limites des niveaux extrêmes de pleine mer et de basse mer. L'échelle de représentation serait du 1/25 000. Ces zones sont déterminées par l'intersection de la topographie côtière avec les plans de niveaux d'eau d'iso-valeurs à des périodes de retour de 5, 10, 25, 50 et 100 ans.
Les spécifications communes à ces trois produits sont les suivantes : densité d'un point à chaque millimètre à l'échelle de représentation, information en chacun des points en L, G déterminé dans le système géodésique RGF93, Z déterminé dans le système de nivellement général de la France (précision en Z supérieure à 10 cm).

L'hydrodynamique côtière

Les informations sur l'hydrodynamique côtière sont destinées à satisfaire les besoins suivants :
- sécurité et optimisation de la navigation en surface, de la navigation sous-marine ou de la mise en œuvre d'engins sous-marins remorqués ou non, de la plongée sous-marine ;
- définition du zéro hydrographique, réduction des sondages hydrographiques par mesure de la hauteur d'eau ;
- action de l'État en mer, enquêtes de police par exploitation des modèles de courant de marée (simulation de dérive d'objets ou de polluants) ;
- modélisation numérique sédimentologique, de dispersion des polluants et des effluents, sélection de sites de rejets ;
- études d'impact, calcul des états limites des ouvrages maritimes (quais, digues...), études statistiques sur les périodes de retour des niveaux extrêmes et de la houle ;
- aménagement du littoral : schéma directeur de la surveillance de l'environnement littoral, SMVM, Contrats de baie ;
- définition des zonages biologiques (nourriceries, frayères, habitats sensibles...), présélection de sites d'exploitation de ressources vivantes.

Les données numériques de référence ressortissant à ce thème sont les suivantes :

* ***Niveau 1 :*** *marée*

Prédiction de marée (Simon, 1994a) sous la forme d'annuaire numérique (PM, BM) et/ou de hauteurs à pas de temps minimum de 5 mn sur l'ensemble des ports de France *via* des logiciels de prédiction de marée.

* ***Niveau 1 :*** *courants de marée de la base Shom* (Pineau, 1998)

Modèle maillé, informations sous forme de constantes harmoniques et d'une fonction permettant d'avoir les courants de marée en tout point et en tout lieu ; échelle de représentation : 1/100 000 ; densité d'un point toutes les 0,5 minutes.

* ***Niveau 2 :*** *points d'observation spécifiques*

Marégraphes, houlographes, courantomètres, points de mesure spécifiques, sémaphores, points de surveillance des réseaux...

* ***Niveau 2 :*** *synthèses hydrodynamiques de l'Ifremer* (Loubersac *et al.*, 1999)

Les représentations sont de type vecteur, maillée (raster) ou combinaison vecteur/raster pour les directions et vitesses des courants maximums, moyens, minimums, les trajectoires à long terme, les résiduelles à long terme, le temps de résidence, la capacité dispersive liée aux courants, l'indice de stratification ; les échelles de représentation prévues vont du 1/500 000 pour les façades maritimes au 1/100 000 pour les sites régionaux, mailles de 1 km à 100 mètres.

Limites et zones administratives

Toutes les activités pratiquées en zones côtières sont concernées par ce thème. La cohérence à l'intérieur du thème est essentielle. Celle-ci doit également être assurée avec le zéro hydrographique et le trait de côte qui conditionnent en grande partie les échelles de représentation, ainsi qu'avec la limite du plateau continental naturel et les limites administratives à terre. Il est souhaitable de conserver un lien entre l'information géoréférencée et l'information juridique correspondante (Guillaumont *et al.*, 1999).

* ***Niveau 1 :*** limites de salure, limites des Affaires maritimes, limites transversales de la mer, limites amont du domaine public maritime, lignes de base, limites aval des eaux territoriales, limites aval de zones contigues, limites aval de ZEE, limites aval du plateau continental juridique, limites en mer des frontières nationales, limites latérales des préfectures maritimes, régionales et départementales, limites communales (réflexion en cours).

* ***Niveau 2 :*** objets zonaux principaux (échelles dépendant des limites qui les composent) : domaine public fluvial et domaine public maritime (distinction naturel/artificiel), eaux intérieures, mer territoriale, zone contiguë, plateau continental juridique, ZEE, zone d'autorité des préfectures maritimes, régionales et départementales, zone des communes en mer.

Exemples d'utilisation pour des applications

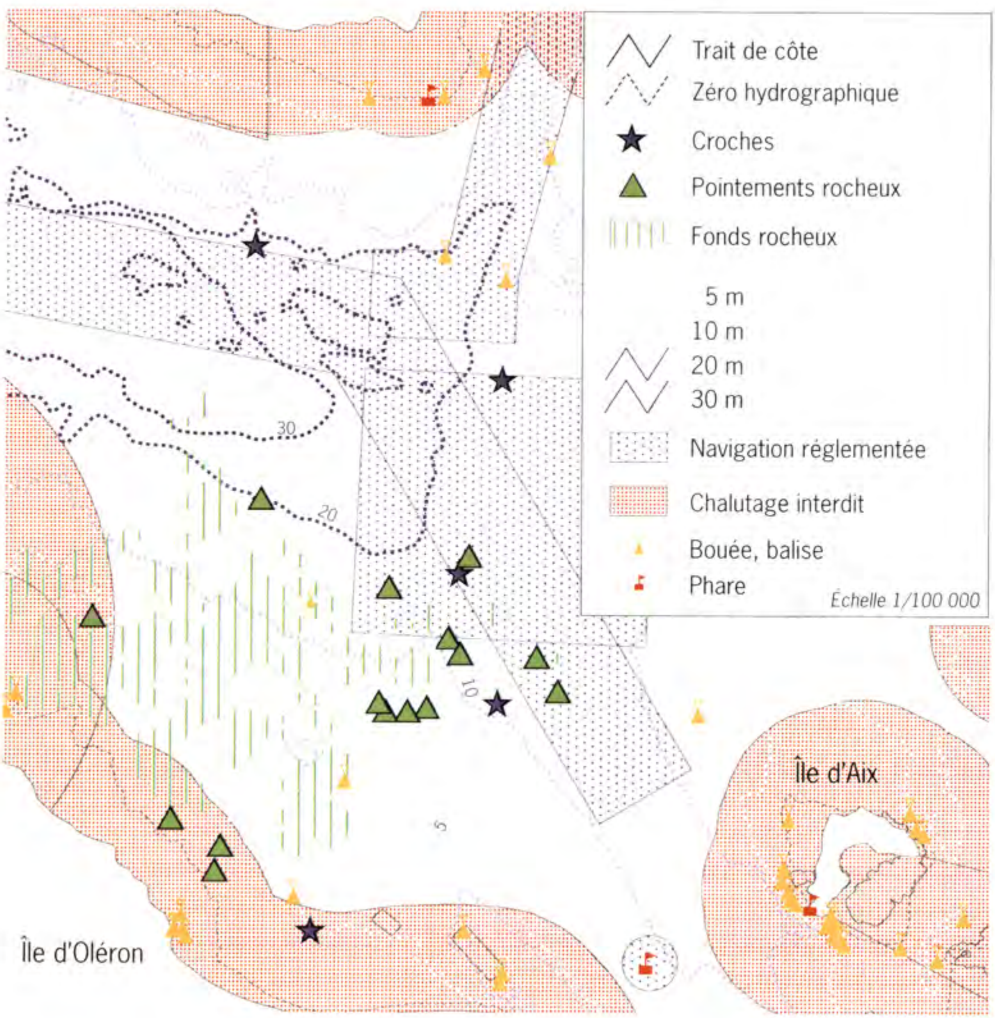
On illustre dans ce chapitre l'utilisation de certaines données de référence vis-à-vis de deux applications : un métier de pêche côtière au chalut et la gestion d'une zone conchylicole.

Application à la pêche au chalut

Sur la figure 1 (zone nord-est de l'île d'Oléron) est représenté un ensemble de données de référence utiles à la pratique de la pêche au chalut à poissons, avec mention de leur niveau de référence :

- le trait de côte et le zéro hydrographique au 1/50 000 provenant du Shom (niveau 1);
- les fonds rocheux, polygones obtenus à partir de la carte 6333G des natures de fond (Garlan, 1993) au 1/50 000 du Shom (niveau 1);

Figure 1
Données de référence utiles à une application de pêche au chalut, zone nord-est d'Oléron.

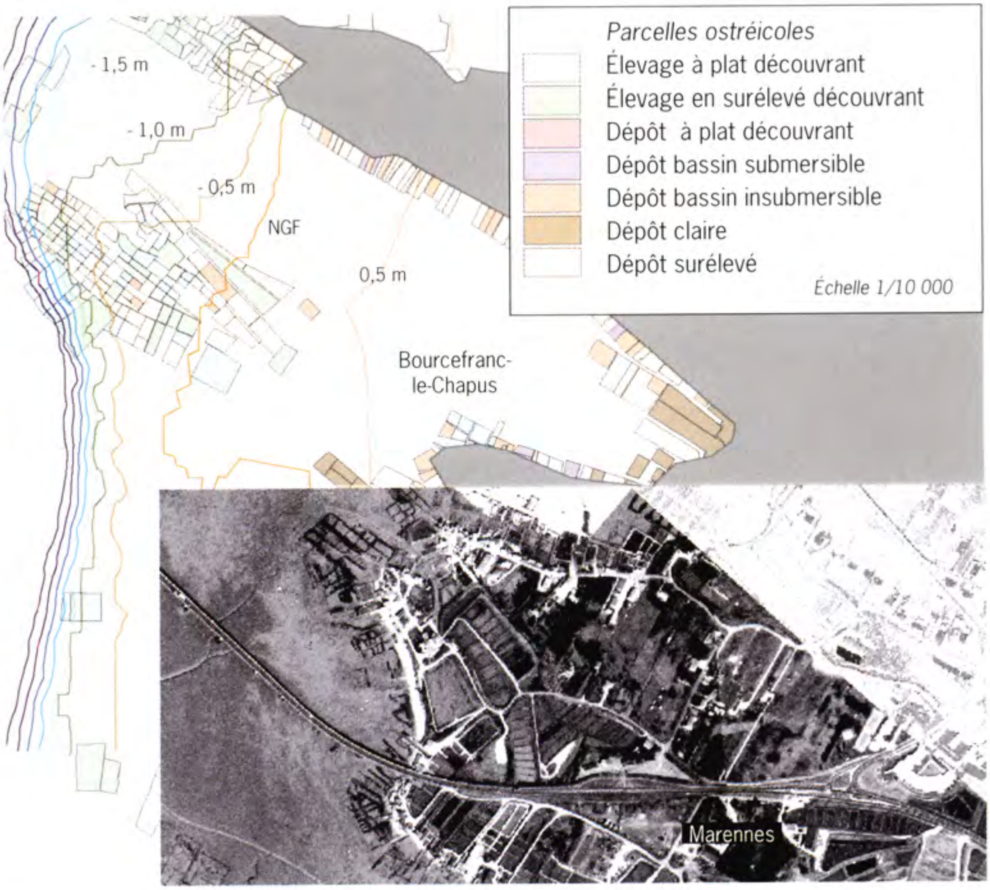


- la bathymétrie apparaissant sous forme d'une sélection d'isobathes provenant de la carte 6333 du Shom au 1/50 000 (niveau 1) ;
- les objets sous-marins en provenance du Shom : épaves, croches rocheuses (niveau 2) ;
- les zones réglementaires contraignant l'activité (niveau 2). Ces dernières consistent en : chenaux de navigation et zones d'attente, câbles sous-marins ou dépôts d'explosifs, zones interdites à la navigation, zones interdites au chalutage, proximité de la côte ou des cultures marines ;
- les marques de navigation (phares, balises, bouées) provenant de la DDE17.

Application de gestion d'une zone aquacole

La figure 2 montre, autour de Bourcefranc-le Chapus, un ensemble de données de référence :
- en tant que fond de carte, une orthophotographie acquise par le Shom au 1/20 000 puis scannée (niveau 2) ;
- le trait de côte au 1/10 000 (niveau 1), issu de la base de données photogrammétrique du Shom (BDPS) ;

Figure 2
Données de référence utiles à une application de gestion d'une zone aquacole, Bourcefranc-le-Chapus, Charente-Maritime.



- les isohypses espacées de 0,5 m sur la zone d'estran, repérées par rapport au nivellement général de la France (NGF) et s'étendant vers le bas jusqu'au zéro hydrographique (niveau 1). Elles ont été obtenues par tracé de contours sur un modèle bathymétrique maillé à la résolution de 20 m résultant du traitement d'un levé au 1/10 000 effectué en 1996 par la DDE de Charente-Maritime ;
- les parcelles ostréicoles (Populus *et al.*, 1997) sont distinguées suivant le type de culture qui y est pratiqué (source Affaires maritimes). Elles sont de niveau de référence 1.

Conclusion

Cet article a présenté succinctement la méthode utilisée par le groupe de travail et un extrait de ses résultats, en cherchant à illustrer la démarche par quelques exemples.
Parmi les points importants qui se dégagent de l'étude figurent :
- l'adoption d'un vocabulaire permettant d'établir une définition commune des objets et de lever des ambiguïtés tenaces ;
- le bilan des données existantes ;
- la hiérarchisation des besoins en données de référence, en allant au-delà des applications usuelles ;
- la mise à plat de la structure des données de référence qui n'obéit plus à des contraintes strictement cartographiques mais à celles de bases de données géoréférencées organisées topologiquement ;
- la réflexion sur la cohérence entre les données maritimes et terrestres à l'interface du trait de côte.

Le rapport du groupe de travail sera prochainement remis aux directions du Shom et de l'Ifremer, avant diffusion élargie aux autres organismes, parmi lesquels les producteurs ou gestionnaires de données et aux usagers potentiels. Cette diffusion devrait permettre d'amender et de compléter cette réflexion, notamment par l'ajout de nouveaux thèmes (les informations statistiques par exemple) ou la validation des produits proposés. Le rapport ne préjuge pas des moyens qui devront être mis en œuvre pour répondre aux besoins.

Sa remise au Cnig pourrait être l'acte fondateur d'un groupe Mer élargi à tous les acteurs concernés (ministères, collectivités, professionnels, associations, industriels...). Ce groupe aurait pour mission de stabiliser les données de référence, d'activer leur mise en œuvre en fonction des besoins et de coordonner l'action des différents producteurs et gestionnaires. En outre, il aurait pour rôle de promouvoir les travaux dans ce domaine au plan international, et notamment européen (Commission européenne, 1999).

Références bibliographiques

Cnig, 1998. L'information géographique française dans la société de l'information. État des lieux et propositions d'action. Version 3.0, mai 1998.

Collectif, 1993. Le livre bleu, schéma de mise en valeur de la mer du littoral charentais. Préfecture de Charente-Maritime, La Rochelle, 125 p.

Commission européenne, 1999. Lessons from the European Commission's Demonstration Programme on Integrated Coastal Zone Management (ICZM). Luxembourg: Office for Official Publications of the European Communities, 93 p.

Garlan T., 1993. Innovation dans le domaine de la cartographie marine au Shom. Rev. Hydrogr. Intern., Monaco, LXX(1).

Guillaumont B., Durand C., 1999. The integration and management of regulatory data in a GIS: an applied analysis of the French coasts. *In:* CoastGIS'99, Brest, sept. 1999. Éd. Ifremer, Actes Colloq., 25, 269-283.

Loubersac L., Salomon J.-C., Breton M., Durand C., Gaudineau C., 1999. Perspectives offertes par la communication entre un modèle hydrodynamique et un SIG pour l'aide au diagnostic environnemental. Caractérisation de la dynamique et de la qualité des masses d'eau côtières. *In:* CoastGIS'99, Brest, sept. 1999. Éd. Ifremer, Actes Colloq., 25, 173-185.

OHI. Dictionnaire hydrographique. Publication spéciale OHI n° 32.

Pineau L., 1998. Les nouveaux atlas de courant de marée. La lettre du Shom aux navigateurs, 15, déc. 1998.

Populus J., Loubersac L., Prou J., Kerdreux M., Lemoine O., 1997. Geomatics for the management of oyster culture leases and production. *In:* CoastGIS'97, Second International Symposium on GIS and Computer Mapping for Coastal Zone Management, University of Aberdeen, Aug. 1997.

Simon B., 1994a. La marégraphie. *In:* Élévation du niveau de la mer le long des côtes de France : mesures, impacts, réponses. Paris, déc. 1993. Ministère de l'Environnement, 67-75.

Simon B., 1994b. Statistiques des niveaux marins extrêmes le long des côtes de France. Rapport d'étude Shom, 001/94, 78 p.

Troadec P., Le Goff R. (coord.), 1997. État des lieux et des milieux de la rade de Brest et de son bassin versant. Phase préliminaire du contrat de baie de la rade de Brest. Édition Communauté urbaine de Brest, 335 p., 88 cartes.

Putting the coastal zone information puzzle together

Andrew G. Sherin[(1)], David W. Cody[(2)], Éric L. Theriault[(3)]

(1) Natural Resources Canada, Geological Survey of Canada (Atlantic),
P.O. Box 1006, Dartmouth, Nova Scotia, Canada B2Y 4A2 - sherin@ago.bio.ns.ca

(2) Nova Scotia Department of Housing and Municipal Affairs,
Nova Scotia Geomatics Centre, 160 Willow St., Amherst, Nova Scotia, Canada B4H 3W5

(3) Environment Canada, Environmental Protection Branch, 45 Alderney Dr., Dartmouth, Nova Scotia, Canada, B2Y 2N6

Abstract

Successful delivery of Integrated Coastal Management requires access to reliable information from many scientific and regulatory agencies. The present situation in many localities resembles a puzzle which consists of many data sets maintained by many organizations. This paper examines three ongoing programmes from Atlantic Canada with a significant data and information integration component. They are the Nova Scotia Coastal Mapping Program, a series of base maps in support of coastal management in the province; the Atlantic Region Sensitivity Mapping Program of Environment Canada, part of a national initiative to map all coastal areas both as a planning and response tool for oil spills; and the Coastal Information System developed by the Geological Survey of Canada (Atlantic). The benefits of completing the puzzle are explored with reference to the successes experienced in these three programmes.

Résumé

La réussite de la gestion intégrée du littoral exige l'accès à une information fiable d'un grand nombre d'organismes scientifiques et de réglementation. La situation actuelle dans nombre de lieux ressemble à un casse-tête dans lequel de larges ensembles de données réglementaires sont conservés par plusieurs organismes. Dans cette étude, on examine trois programmes en cours au Canada atlantique qui présentent une importante composante d'intégration de données et d'information. Ceux-ci sont le programme de cartographie littorale de la Nouvelle-Écosse (Nova Scotia Coastal Mapping Program) qui vise la production d'une série de cartes de base à l'appui de la gestion des littoraux de cette province; le programme de cartographie des zones vulnérables de l'Atlantique (Environnement Canada), qui s'insère dans une initiative nationale visant la cartographie de toutes les régions côtières à des fins de planification et à titre d'outil d'intervention en cas de déversement accidentel d'hydrocarbures; et le système d'information sur les littoraux

developpé par la Commission géologique du Canada (Atlantique). Les avantages de l'assemblage du casse-tête sont explorés en fonction des succès obtenus dans le cadre de ces trois programmes.

Introduction

The creation and improvement of databases and data and information management is one of the important instruments for the sustainable development of coastal zones and their resources (El Sabh *et al.*, 1998; Fabbri, 1998; Huggett, 1998).
The present situation for information in the coastal zone can be characterized by a puzzle, a puzzle apart or a puzzle partially put together. Some of the puzzle pieces fit together. Others don't. To further complicate this picture, the puzzle pieces are owned by different organizations.
The purpose of this paper is to explore some general issues with examples from Atlantic Canada which inhibit or foster the process of developing a well-structured database to support integrated coastal management, the completed puzzle.

Interoperability

Interoperability is an important precursor to put the puzzle together. For a comprehensive discussion of interoperability issues, the reader is referred to the special issue of the International Journal of Geographical Information Science, Volume 12, Number 4, June 1998. Two papers in that special issue are of particular note.
Laurini (1998) describes difficulties to overcome: the diversity of spatial representations, the diversity of global projections, the diversity of values for the same item from different organizations, the diversity of spatio-temporal sampling, the variability of definitions over time and space, discrepancies in co-ordinate values, and discrepancies in boundary alignment.
Bishr (1998) defines six levels of interoperability. He states there is no known GIS that provides interoperability at the data model level and application semantics level.
He goes on to say that "geographical objects stored in independent remote databases can vary in their geometric syntactic representation, in their class hierarchies, or in their semantics, even though they may refer to the same real world feature."
Semantic heterogeneity can be a significant barrier to interoperability and is usually the source of most data sharing problems.
For coastal data specifically, Kucera (1995) cites several difficulties which are different from terrestrial data: three spatial dimensions in air, sea and underground, and the dynamics of spatial data in fluid motion.
Laurini (1998) also defines inter-organizational problems: copyrights, access rights, results property, ownership of products made from data from different organizations, accounting problems, and difficulties

during prototype implementation or operational problem responsibility or resolution.

Evans (1997) suggests that several organizational shifts are necessary for agencies involved in data sharing. Data managers within organizations need to take responsibility for providing reliable data sets to external users. Analysts and decision-makers need to depend on outside data for essential tasks. Organizations need to learn to live with different data conventions. He goes further to suggest that to reap the benefits of information sharing infrastructures "deeper-than-expected" changes in organizations and inter-organizational relationships may be required.

These are changes leading to a state of dynamic interdependence between data sharing organizations.

From a review of the long lists of problems these authors have cited, it is clear that interoperability both technical and organizational and the task of putting together the coastal zone information puzzle are challenging.

The Atlantic Canada Programmes

In this section our experiences and modest attempts to meet the challenge are described in terms of the development and implementation of three programs from Atlantic Canada. The experiences are divided into issue categories, issues which either inhibited or fostered the processes of development and implementation.

The Nova Scotia Coastal Series

The Nova Scotia Coastal Series (NSCS) provides a single source of base mapping for coastal mapping users, portraying information on both land and water features of Nova Scotia's coastline. The program is managed by the Nova Scotia Department of Housing and Municipal Affairs through the Nova Scotia Geomatics Centre. A portion of one of the maps from the series is shown in figure 1. This three-year mapping initiative is made possible through the funding cooperation of several provincial government departments including Housing and Municipal Affairs, Economic Development and Tourism, Fisheries and Aquaculture, Natural Resources, and Environment. Data for the series came from three organizations. Topographic data came from the Provincial Department of Housing and Municipal Affairs, forestry data from the Provincial Department of Natural Resources and electronic navigation chart (ENC) data from the Canadian Hydrographic Service of the Federal Department of Fisheries and Oceans. The map series is not authorized for navigational use although it resembles a hydrographic chart on the water side of the shoreline. The terrestrial side of the shoreline is much richer in thematic content than a hydrographic chart. The uses for this map series include aquaculture planning and regulation, nearshore fisheries' management, recreational and tourist facility development and operation and other coastal zone management activities.

Figure 1 - Part of map number 50 442500 66000 21B08 (Church point) from the Nova Scotia coastal series near Triverton, Nova Scotia, Canada (location A in figure 3). Scale shown is approximately 1:75,000.

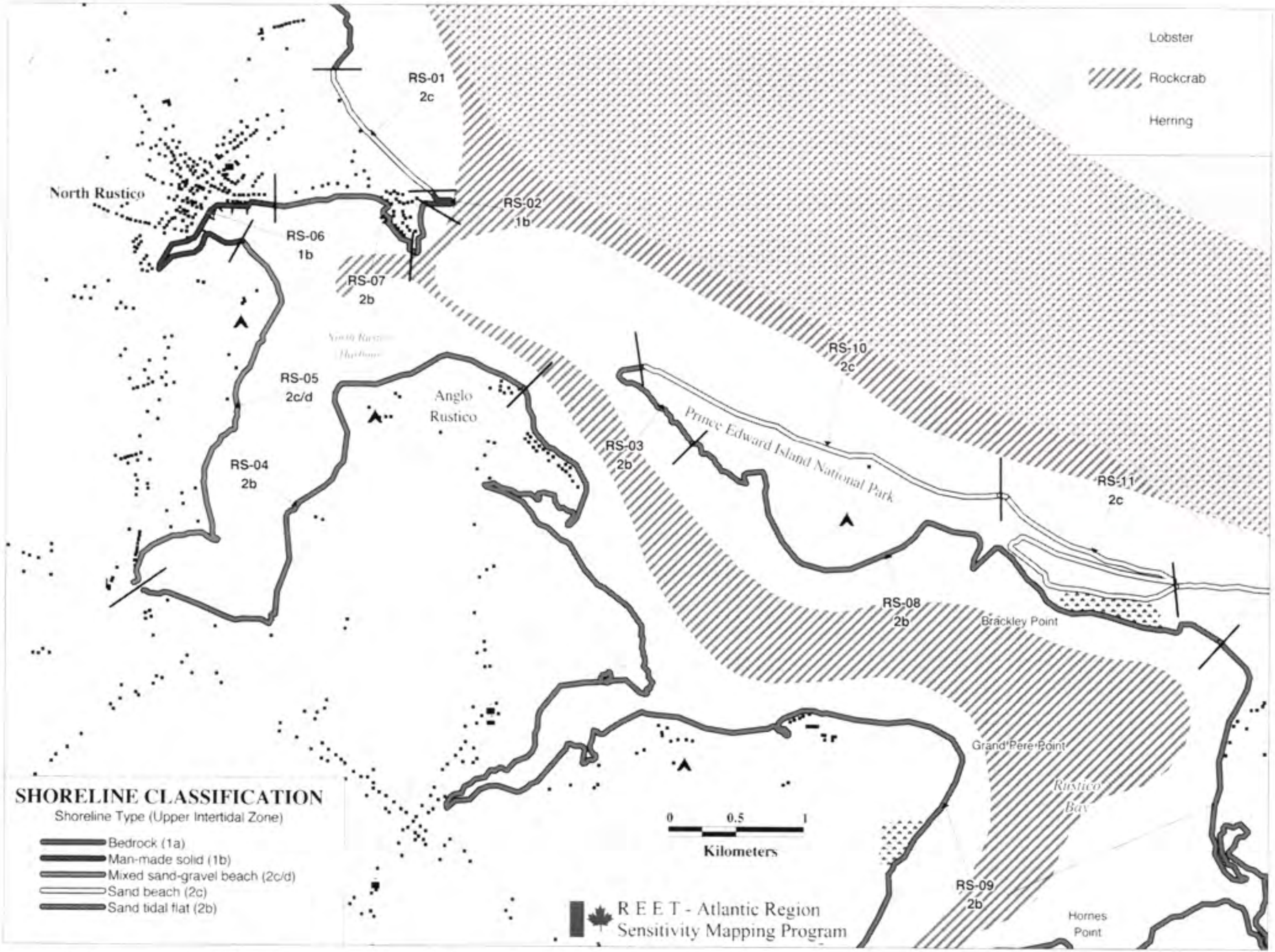


Figure 2 - A coastal geomorphology and shellfish resources map from the Atlantic region sensitivity mapping program for Rustico Bay, Prince Edward Island, Canada (location B in figure 3). Scale shown is approximately 1:50,000.

The Atlantic Region Sensitivity Mapping Program

The Atlantic Region Sensitivity Mapping Program (ARSMP) of Environment Canada is part of a national initiative to map all coastal areas both as a planning and response tool for oil spills. The geographic coverage of the Atlantic Region Sensitivity Mapping Program is the coastal area of Atlantic Canada including the provinces of Nova Scotia, New Brunswick, Prince Edward Island and Newfoundland. A sample map from the ARSMP is shown in figure 2. Access to and management of multiple data sets such as natural, cultural and man-made features vulnerable to oil spills are facilitated by the use of a desktop mapping program. These data are primarily obtained through partnerships and agreements with other government departments including the federal departments of Fisheries and Oceans and Natural Resources, Parks Canada, all the provincial departments of Environment and Fisheries and Aquaculture, provincial archeologists, provincial centres of geomatics, some community groups and industry.

The Coastal Information System

The Coastal Information System (CIS) of the Geological Survey of Canada (GSC) is a mapping program which exploits the data set of aerial video collected by the GSC.

Figure 3 shows the extent of the video collection. Figure 4 and figure 5 show sample maps generated from the CIS. The purpose of the CIS is to support the coastal process research activities of the Geological Survey of Canada and disseminate data to external users. To do this the CIS stores

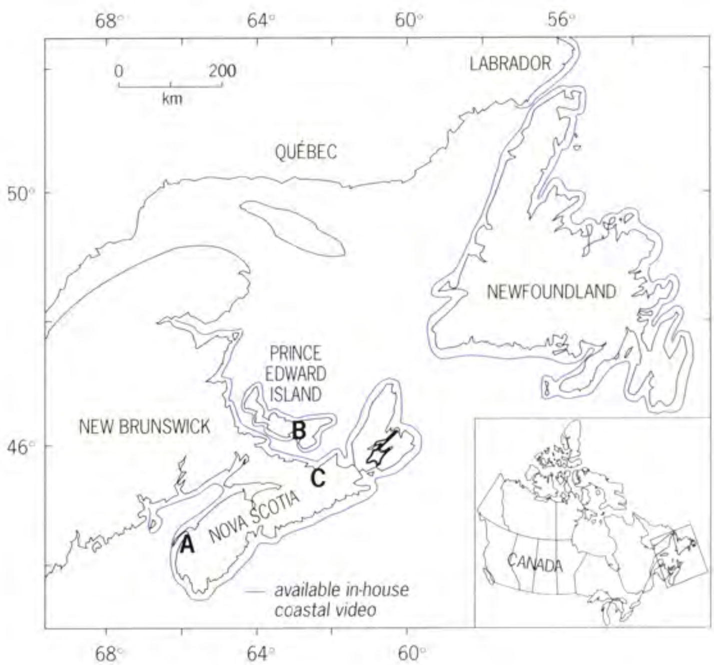


Figure 3
Geographical coverage of coastal aerial video collected by the Geological Survey of Canada and oil companies in Atlantic Canada. A is the location of figure 1. B is the location of figure 2 and C is the location of figures 4 and 5.

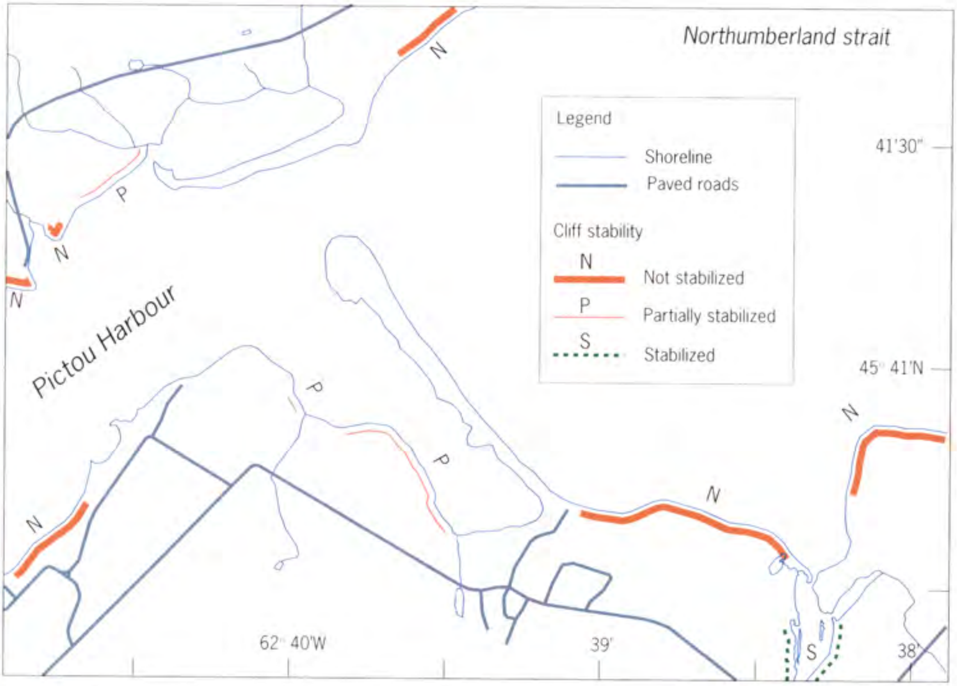


Figure 4 - Stability of unconsolidated cliffs for Pictou Harbour, Nova Scotia, Canada. A map product from the Coastal Information System (location C in figure 3). Scale shown is approximately 1:25,000.

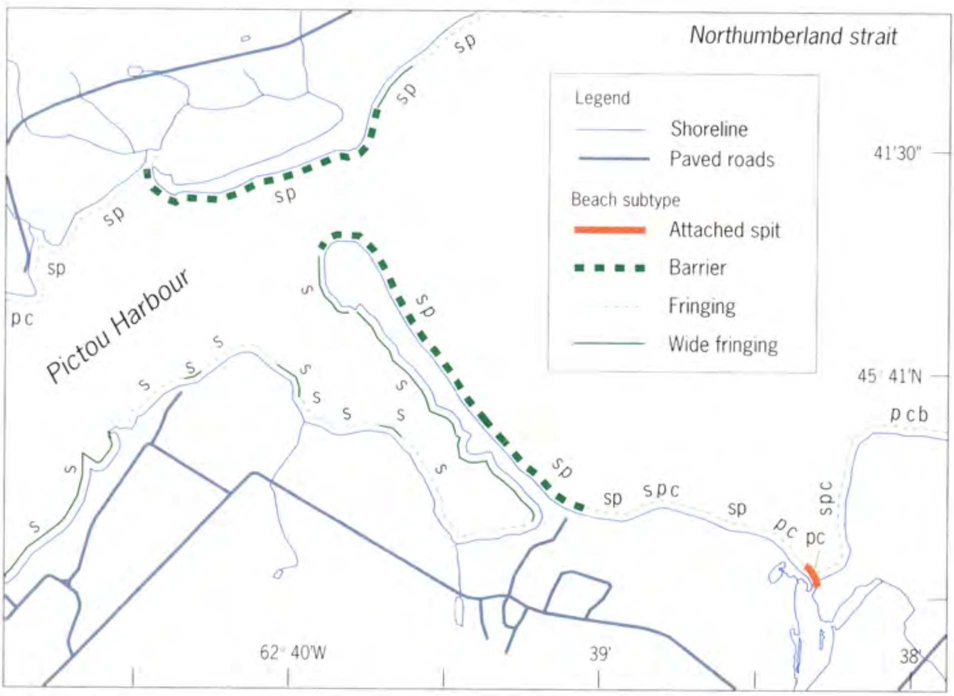


Figure 5 - Beach subtype for Pictou Harbour, Nova Scotia, Canada. A map product from the Coastal Information System (location C in figure 3). Beach material is presented as text: pc = pebble, cobble; pcb = pebble, cobble, boulder; s = sand; sp = sand, pebble; and spc = sand, pebble, cobble. Scale shown is approximately 1:25,000.

coastal geomorphological and textural data in a geographic information system, facilitates user-specific queries and data analysis, and integrates these coastal data with other applications to enhance coastal interpretations and coastal mapping. The Coastal Information System is described in detail in Sherin & Edwardson (1996).

Our Experience

The Issues

In the development of the Nova Scotia Coastal Series (NSCS), variability in the representation and accuracy of coastlines was encountered in the ENC data. Data from the ENCs other than shorelines was therefore reconciled to the shoreline from the topographic data which was at a consistent scale and covered the whole province of Nova Scotia. Since the NSCS conforms to the standard 1:50,000 National Topographic System map sheet layout, chart limits had to be included for the creation of the polygon boundaries between ENCs of differing scales.

The development of the NSCS required the merging of 1:10,000 topographic and forestry data sets into seamless 1:50,000 data sets. The process revealed data quality problems at the map boundaries of the 1:10,000 maps which had to be rectified. The process provided a previously unexplored avenue for quality control and enhancement of both the forestry and topographic databases.

Confidential information in the forestry database used for the NSCS was generalized so that information on forest stands of an individual owner could not be identified.

Topographic data for the NSCS was converted from the ATS77 horizontal datum used by provincial mapping agencies in Atlantic Canada to the NAD83 horizontal datum to match the requirements of the user community and the datum of the ENCs.

In the Atlantic Region Sensitivity Mapping Program (ARSMP), traditional ecological knowledge of nearshore fisheries and other coastal resources were incorporated. Manipulation of the data structures was necessary to make this data compatible with the ARSMP structure.

Incompatibilities related to definitions and semantics may be insurmountable. Bishr (1998) gives two examples of semantic incompatibility. Naming semantic incompatibility (*e.g.* watercourse *versus* river) can normally be corrected using tools like a thesaurus. Bishr (1998) suggests that cognitive semantic incompatibility (*e.g.* the differing view and purpose of streets held by pavement managers and marketing analysts) requires a more complex system of rules and constraints to map between the roles and definitions different disciplines may attribute to the same real world object.

These types of incompatibilities were avoided in the ARSMP and the CIS by using geomorphological classifications which share a common origin. They are both refinements of the system developed for the Government of the Province of British Columbia (Howes *et al.*, 1994;

Owens, 1994). The use of common definitions and a common classification enables the immediate and direct use of the data by both organizations and by others sharing the semantics, even if the systems have different data structures or different GIS softwares. A portion of the geomorphological classification used in the CIS is shown in table 1.
Aquaculture site data for the ARSMP was obtained from provincial agencies.

Table 1 - Selections from the CIS classification system for geomorphic form (after Edwardson, unpublished).

Supertypes	Types	Subtypes	Features (selected)
Solid	Cliff	Vertical, steep, overhanging, terraced.	Unconsolidated over solid, talus cone, discontinuous, arch, cave.
	Outcrop < 40°	Ramp, irregular ramp, irregular, undulating, cliff foot, smooth.	Unconsolidated over solid, discontinuous.
	Platform	Smooth, irregular.	Discontinuous.
Unconsolidated	Cliff	Vertical, steep, overhanging.	Slump block, gullied, drumlin, not stabilized, partially stabilized, stabilized.
	Slope < 20°	Smooth, irregular.	Not stabilized, partially stabilized, stabilized.
	Beach	Fringing, wide fringing, pocket, barrier, tombolo, attached spit, detached barrier.	Cusp, berm, wave cut, washover channel, washover fan, storm ridge, relict ridge, rip channel, discontinuous.
	Dune	Initial dune, foredune, primary ridge, multiple ridge, parabolic, transverse, dome, sheet, relict.	Blowout, wave cut, not stabilized, partially stabilized, stabilized.
	Boulder	Boulder barricade, clastic fringe, nearshore scattered boulders.	Discontinuous.

Permission of the originating data provider is required before distributing the data to others. For some archeological site information, distribution to other parties is forbidden to ensure conservation of the site. This data can only be shared in the event of an oil spill.
Base map data for ARSMP and CIS were purchased or otherwise acquired from third parties. Copyright has been retained by these organizations and licensing restricts the distribution of the base map data to other parties. Environment Canada has become a licensed data distributor on behalf of their base map data provider (Geomatics Canada) to enable easier distribution of thematic data from the ARSMP system. Distribution licenses and possibly royalty agreements will be necessary for the public distribution of base map data from the CIS. Multi-user licensing and subscription agreements are new methods which are in use in Atlantic Canada to encourage the use of base map data and reduce the financial burden to the user agency.
In the ARSMP, traditional ecological knowledge was incorporated. This data was collected by members of coastal communities with financial and technical support from the Federal Department of Fisheries and Oceans. The ownership of the intellectual property has yet to be determined.

Partnerships

There is a requirement for partnering organizations to modify their methods. These may be modifications to accommodate their partners' data within their own organization or modifications which benefit their partners. The three organizations contributing to this paper are committed to the development and maintenance of partnerships for the delivery of their products and services. They recognize that partnerships improve organizational effectiveness. Partnerships enable the organizations to respond to larger opportunities and can actually create new opportunities. They allow each organization to concentrate on its core competencies and to benefit from synergistic relationships. A partner can bring new clients for an organization's products. Together, partners can develop new products for their existing or new clients. Three partnerships are described below.

The primary information source for geomorphic interpretations for both the ARSMP and the CIS is oblique aerial video with expert voice commentary collected by the Geological Survey of Canada in collaboration with the Canadian Coast Guard, the Federal Department of Fisheries and Oceans and oil companies. Aerial photos were used as a secondary source where video coverage was unavailable. Archeological site data for the ARSMP existed only in hard-copy. Agreements were negotiated for the conversion to digital form and the sharing of the resulting digital information.

The partnership for the NSCS resulted in the development of new products for the Nova Scotia Geomatics Centre: a digital database for GIS users, a 1:50,000 scale hard copy monochrome map series, and a print-on-demand colour map series. The partnership also brought new clients, including aquaculturists, nearshore fisheries' managers, coastal zone management authorities, recreational enthusiasts and tourist facility operators to the provincial agencies and the Canadian Hydrographic Service.

The NSCS also represented a new use for the existing data sets of the three collaborating organizations.

A Coastal Zone Information Infrastructure

Masser (1999) in his review article summarizes the objectives of all spatial data infrastructures: "To promote economic development, to stimulate better government and to foster environmental sustainability". These objectives are compatible with the objectives of Integrated Coastal Management (ICM). In Atlantic Canada, economic development is a major concern for the people and policy makers. The cross jurisdictional nature of the coastal zone between federal, provincial and municipal governments in Canada suggests that partnerships for data sharing would provide better government. Finally, sustainability is key to ICM. A spatial data infrastructure for the coastal zone would seem to be a natural vehicle to provide information for ICM. A Coastal Zone Information Infrastructure is a vehicle for putting the puzzle together.

The Canadian Council on Geomatics has initiated a program called the Canadian Geospatial Data Infrastructure (CGDI) (Labonte *et al.*, 1998). Its components are:

- a common national framework of core data sets and more specific databases ;
- a client-centred access *via* an Internet-based clearinghouse ;
- international standards ;
- a supportive policy environment ;
- partnerships.

Federal, provincial and territorial agencies in Canada have adopted a Statement of Principles on partnerships, to gather data in partnerships, gather data only once and to share and use data many times.

A coastal zone information infrastructure for Atlantic Canada will fit into the context of the CGDI. Our experience suggests that a coastal zone information infrastructure requires standards which go beyond the standards for the base map. They must include standards for thematic information. Table 2, a summary of a number of authors from Kucera (1995), outlines the data needs for a coastal GIS or coastal zone information infrastructure. Metadata must go beyond simple Database Directories. Agreements between organizations have to go beyond Memoranda of Understanding towards integrated operations. Delivery mechanisms must be more functional.

Table 2 - Data needs of a coastal GIS (after Kucera, 1995).

Geomorphology	Shoreline, elevation, drainage, bathymetry; ocean sediments, coastal soils, ocean and shoreline geology; aquifer data.
Dynamic factors	Tides, currents and wave energy; meteorology; seasonal effects.
Biogeography	Intertidal habitat; water chemistry; fisheries; birds; mammals; marine invertebrates and plants.
Political geography	Jurisdictional boundaries; administrative boundaries, legislative boundaries, cadastral boundaries.
Economic geography	Land, shoreline and offshore use; land cover; well locations, ownership, composition; building permits; zoning; episodic waste release; sewage treatment facilities; sport fishing and other recreational harvesting; marinas and smallcraft harbours.
Transportation links	Ferry routes and other marine transportation; airports; road network; navigable rivers.
Special-status areas	Archeological sites; wildlife sanctuaries, ecological preserves; national, state, provincial, and local parks; First Nations' lands.

Conclusions

Partnerships are necessary to put the puzzle together. Partnerships can be of many flavours, formal and informal, but must bring a net benefit to all parties in the partnership. Partnerships help expand an organization's client base and product base.

Organizational commitment is key. Commitment to the partnership is demonstrated by its flexibility to adjust its requirements to meet the needs of the other partners and the organization's willingness to change its methodologies, standards, etc.

New uses of data often require the reevaluation of the quality assurance procedures and standards used by the organization. This reevaluation can often be triggered by use of the data by partners or clients for new purposes.

Copyright and licensing restrictions are impediments but realities. They can be overcome by the development of formal agreements or by finding alternative sources of data and information.

Restriction on the release of some types of information for conservation, commercial propriety, privacy or other sensitivity is another reality and needs to be accommodated.

The use of common definitions and classification systems encourages the widest utilization of the information.

Conversions will be necessary for the foreseeable future. System to system conversions are common place. Data structure conversions are possible especially if data structures are designed with careful systems analysis and data modeling. Datum conversions are becoming easier. Conversions from hard copy to digital formats are still expensive and time consuming, which is a good reason to develop partnerships to share the cost.

The development of a coastal zone information infrastructure requires the organizational commitment to a new type of multilateral partnership. Its implementation at a basic level is prevented primarily by the absence of organizational will. There are however technological limits in data delivery mechanisms (*e.g.* immature Internet technologies). There is the limited availability of effective data management tools for data from a dynamic coastal environment. These factors prevent a full implementation of an information infrastructure and make the assembly of the puzzle incomplete.

Acknowledgments

This paper is Geological Survey of Canada contribution number 1999 144.

Bibliographic references

Bishr Y., 1998. Overcoming the semantic and other barriers to GIS interoperability. Intern. J. Geogr. Inform. Sci., 12, 299-314.

El-Sabh M., Demers S., Lafontaine D., 1998. Coastal management and sustainable development: From Stockholm to Rimouski. Ocean Coast. Manage., 39, 1-24.

Evans J.D., 1997. Infrastructures for sharing geographic information among environmental agencies. PhD Thesis, Massachusetts Institute of Technology, Cambridge, June, 1999.

Fabbri K.P., 1998. A methodology for supporting decision making in integrated coastal zone management. Ocean Coast. Manage., 39, 51-62.

Howes D.E., Harper J., Owens E., 1994. British Columbia Physical Shore-Zone Mapping System. British Columbia Resources Inventory Committee, Victoria, 72 p.

Huggett D., 1998. The role of federal government intervention in coastal zone planning and management. Ocean Coast. Manage., 39, 33-50.

Kucera G. L., 1995. Object-oriented modeling of coastal environmental information. Mar. Geodesy, 18, 183-196.

Labonte J., Corey M., Evangelatos T., 1998. Canadian Geospatial Data Infrastructure (CGDI): Geospatial information for the knowledge economy. Geomatica, 52, 194-200.

Laurini R., 1998. Spatial multi-database topological continuity and indexing: a step towards seamless GIS data interoperability. Intern. J. Geogr. Inform. Sci., 12, 373-402.

Masser I., 1999. All shapes and sizes: the first generation of national spatial data infrastructures. Intern. J. Geogr. Inform. Sci., 13, 67-84.

Owens E.H., 1994. Coastal Zone Classification System for the National Sensitivity Mapping Program. Environment Canada, Dartmouth, Nova Scotia, 14 p. and appendices.

Sherin A.G., Edwardson K.A., 1996. A coastal information system for the Atlantic provinces of Canada. Mar. Technol. Soc. J., 30(4), 20-27.

Coastal zone management information for the South-West of England: the Atlantic Living Coastlines Project Coastal Information Focus Group

Tony Moore[1], Kevin Morris[1], Philip Moore[2], Rachael Bayliss[2]

(1) Centre for Coastal and Marine Sciences, Plymouth Marine Laboratory, Prospect Place, Plymouth, PL1 3DH, Devon, UK - abm@ccms.ac.uk

(2) Atlantic Living Coastlines Project, University of Plymouth, Drake Circus, Plymouth, PL4 8AA, Devon, UK.

Abstract

In Devon and Cornwall (Southwest England), coastal zone data and information exist in disparate formats, are geographically distributed amongst numerous local authorities and groups, and are subject to the global trend of exponential growth. As part of the European Union Atlantic Living Coastlines Project (ALC), an inventory of such data and information has been compiled by the Coastal Information Focus Group (CIFG) from questionnaire replies and augmented by follow up meetings. This, along with the experience of existing information systems has contributed to the design of three system templates or examples - employing 'geographical', 'dialogue' and 'list' access to metadata. These were considered through a consultative seminar, (Info-Coast: the Local Challenge), comprising the CIFG and a cross section of local coastal zone managers, planners and researchers. This paper outlines the findings of the seminar, which will feed into the development of a future demonstration system which will in turn reinforce an integrated coastal zone management information strategy.

Résumé

Dans les comtés du Devon et de Cornouailles (sud-ouest de l'Angleterre), les données et les informations de la zone côtière qui existent dans des formats disparates, sont géographiquement réparties dans de nombreuses autorités et groupes locaux, et sont sujettes à la tendance globale de croissance exponentielle. En tant qu'élément du projet de l'Union européenne « Atlantic Living Coastlines (ALC) », un inventaire des données et des informations a été effectué par le groupe de réflexion sur les informations côtières (CIFG) à l'aide des réponses aux questionnaires et a été complété par des réunions ultérieures. Ceci, grâce aux systèmes d'information existants, a contribué à la conception de trois exemples de système - la méthode géographique, la méthode « dialogue » et la méthode « liste » pour donner accès aux métadonnées.

Ceux-ci ont été mis en valeur lors d'une conférence d'experts (Info-Coast : the Local Challenge), comprenant le CIFG et une partie des dirigeants locaux de la zone côtière. Cet article rapporte les résultats de la conférence qui entreront dans le développement du futur système de démonstration et renforceront la stratégie intégrée dans la gestion de l'information de la zone côtière.

Introduction

The amount of data and information for coastal zone management is growing at a phenomenal rate (*e.g.* the exponential growth of environmental treaties since 1950; French, 1995). However, it has been little over a decade since the issue of data and information started appearing in the coastal zone management literature in its own right. From an analogue viewpoint, Hooke (1988) stressed the need for "cataloguing and inventories", bringing together the information at the base of policy implementation and design. There are direct parallels with this and the current metadata provision issue.

Data and information bases are essential tools for current ICZM, helping reduce a high level of uncertainty and providing decision makers with the means of identifying relevant coastal issues (Unep, 1995; French, 1997). The use of data and information in the coastal zone has largely been scientific in nature and specialized, having a marginalising effect on information, which may have the effect of loss of contact with the coastal stakeholder (Davos, 1998). A consultation process that involves the coastal stakeholder from the beginning, making use of their perceptions and access to relevant technology, was recommended. This was stressed in Agenda 21 of the Rio Earth Summit (French, 1997).

Coupled with this desire to consult with the stakeholders is a move towards the holistic view, with wide-ranging information taken into account (Doody, 1996). Recently, data and information have been collected and collated for numerous individual projects of local scale. This has meant that there is a large volume of data, but it is fragmented, leaving substantial gaps. The data may also be largely undocumented, so it may be of uncertain quality. An overall strategic viewpoint is called for, where these gaps can be identified and prioritized, making for an issue and user-led situation, as opposed to a data-led situation (Busby, 1999; EC, 1999).

A call for a holistic viewpoint is also a call to physically integrate data and information. Historically, this has been difficult and expensive to do (disparate locations, incompatible formats) and has been regarded as one of the most complex tasks in data management (Busby, 1999; Unep, 1995). A case in point is the effort made to collate data for the Land-Ocean Interaction Study (LOIS) Overview CD-ROM (Morris *et al.*, 1999).

The use of metadata (or 'data about data') has become a way to bring data together into one base without physically integrating them. By bringing summary information to the attention of users, the metadatabase facilitates the discovery and usage of disparate data sets (in effect, acting as a catalogue or shop window). The collation of metadata is itself time-consuming and difficult. Examples include the Joint Nature Conservancy Committee (JNCC) Coastal Directories Project (Doody, 1996).

The findings of the European Union's Demonstration Programme on Integrated Coastal Zone Management (ICZM) (EC, 1999; Doody *et al.*, 1998) agree with these issues, particularly supporting the construction and dissemination of metadata sets to identify and access available data, using an ICZM 'observatory' to disseminate generic good practice and general knowledge and simple, user-friendly software development, involving user feedback.

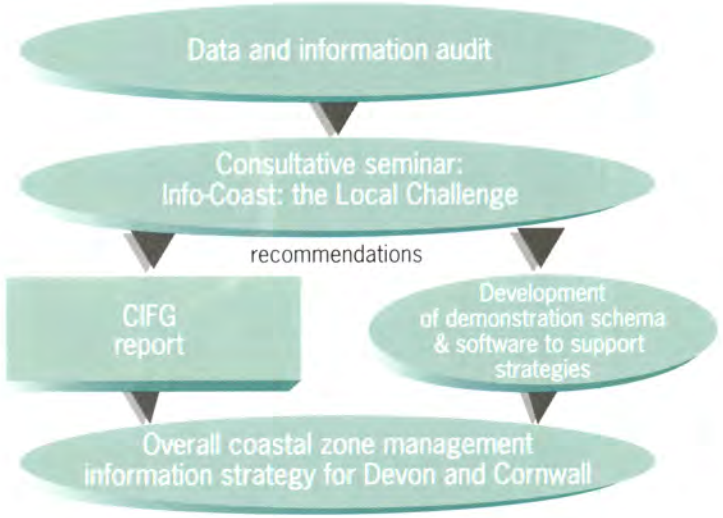
Atlantic Living Coastlines and the Coastal Information Focus Group

The Atlantic Living Coastlines project is part of the EU Demonstration Programme. ALC is funded (1998-2000) through the TERRA (DG XVI) programme and part of the CoastLink network, with a main aim of developing an ICZM strategy for the counties of Devon and Cornwall in the south-west of England. In tandem with this, is an integrated coastal zone management information strategy, backed up with recommendations for a Coastal Zone Management Information System (CZMIS). The development of the strategy is the major task facing the ALC Coastal Information Focus Group (CIFG), one of four focus groups. Together, the focus groups have examined the current CZM initiatives that are already present in Devon and Cornwall, building on their experiences and demonstrating their success. All the lessons learnt from within the CoastLink network will feed into future EC policy development, leading to informed guidance for Coastal Zone Management in Europe in the next millennium.

The CIFG has been working to identify and review the current information resource 'status' of Devon and Cornwall, and make proactive recommendations on practical mechanisms for establishing a Coastal Zone Management Information System (CZMIS).

A large amount of information related to the coastal zone of Devon and Cornwall already exists. However, the information is held in different locations and in different formats. The CIFG (fig. 1) has overseen an audit of the current information (including systems, databases and requirements) held amongst the various organizations in Devon and Cornwall. The audit results influenced the design of example software mechanisms (called 'templates') facilitating data access. Through a consultative seminar, the CIFG has taken user feedback and recommendations on the templates and in general to develop best practice and mechanisms for storing and delivering the key information to relevant sectors of the coastal community.

Figure 1
The Coastal Information Focus Group process model.



Data and information audit of coastal practitioners

This initial stage provides the basis for future work by identifying the current sources of information held by other establishments relevant to coastal zone management in Devon and Cornwall. An analysis of this audit provided the basis for discussion during the consultative seminar, helping to determine future demonstration software.

Questionnaire and follow-up interviews

The first stage of this audit was a short questionnaire, which was sent to over 300 people working in coastal zone management across Devon and Cornwall (local authorities, academics, estuary managers, harbour masters, fisheries, leisure, local wildlife trusts, national environmental institutions). The questions were designed to give an idea of the CZM data and information base, and covered subjects such as data theme (physical, socio-economic, etc.), how data is stored (paper, database, GIS, etc.), and methods of access to the data (what software was used). The responses were augmented by an ongoing series of meetings with the data holders, where data and information holdings were described in further detail to fill in various categories of metadata - see next section.

The majority of respondents thought that a CZMIS would be useful, but mostly as a provider of metadata in the first instance, as opposed to full data access, perceiving that the latter would pose insurmountable issues of copyright and sensitivity. It is important that people have access to data, and a metadata system would facilitate this through:

- knowing where to look (metadata can save time trawling through the Internet);
- knowing what exists is more important than accessing actual data;

- being a useful starting point before moving on to a more complex information system;
- minimising replication of coastal work in Devon and Cornwall.

There was a concern to ensure that such a system is easy to use. GIS, for example, is perceived as too complex. This would involve hiding advanced and complex system functionality that can put off potential users, moving towards an intuitive user-friendly interface. There was also a perceived over-emphasis on digital information - making sure that decision making is not replaced with a computer system and that human contact is maintained. This has been reflected in the participation of users in the development of an ALC CZMIS from an early stage to ensure relevance and applicability.

Finally, there was a need to maximise use of network technology (*e.g.* Internet) to integrate and make available large amounts of quality-assured data and information to the user.

Metadata

Metadata is 'designed for description of the contents of a data set' (Goodchild, 1998). The user will ask general questions about a data set's suitability for use; these are then translated into metadata categories (*e.g.* What data exist? Are they of use to me? Can I see a sample? How do I get them?). The most widely known of metadata standards are those specified by the US Federal Geographic Data Committee (Content Standards for Digital Geospatial Metadata) for use with the National Geospatial Data Clearinghouse (FGDC, 1998). This is a distributed network that allows public and private data providers to publish their spatial data. The broad categories and some of the fields have been adopted for this project; for data quality, the fields suggested in the UK Association for Geographic Information (AGI) standards were used (AGI, 1999):

- Identification Information (*e.g.* title, spatial coverage, period, access);
- Data Quality Information (*e.g.* thematic, temporal, spatial accuracy);
- Spatial Data Organization Information (*e.g.* raster, vector, postcodes);
- Spatial Reference Information (*e.g.* projection, datum, co-ordinate system);
- Entity/Attribute Information;
- Distribution Information (*e.g.* originator/owner details, charges, formats);
- Metadata Reference Information (Currentness of metadata).

It is perceived to be normal for organizations to continue to establish their own standards, while aligning themselves in principle to the above standards.

For an example of Web-based metadata access systems, the European Directory of Marine Environmental Data (EDMED) aims to form a comprehensive reference to European marine environmental data. This is for the benefit of marine scientists, engineers and policy makers, to identify and facilitate access to useful data through a list-based interface (BODC, 1999).

Other systems

Other systems were reviewed, including the HelFal Community Information System (Green, 1995) and the FMG InfoAtlas (Ricketts, 1992), as the problems faced and issues raised during their design, construction and operation bear on system development in the ALC CIFG. The systems were specifically designed to be user-friendly, and some pertinent issues came out of their development, including data protection, copyright (HelFal), an appropriate definition of user needs, networking (FMG InfoAtlas) and a need for system maintenance once it has been developed (both systems).

Consultative seminar: Info-Coast - the Local Challenge

Through this consultation exercise, feedback to the coastal community on the results of the audit, and a forum for discussion on the information requirements for effective progression of coastal management in Devon and Cornwall, were provided. Final recommendations for a CZMIS were borne out of the workshop process through the assessment of three demonstration templates for specific case studies. The consultative seminar utilised techniques based on round table discussions, outlining the positive and negative attributes of the templates and identifying any other concerns.

The demonstration templates

Each template depicted a specific method of access to the same information: geographical query, dialogue query and list query. For each of the templates, a case study had been assigned, the range of case studies providing geographical balance and issue balance.

The case study for the geographical query template was oil pollution in the Taw-Torridge Estuary, North Devon (fig. 2). It was the most geographically extensive of the case studies, providing more of a challenge for the map-based representation. It was programmed in Java, ensuring portability on the World Wide Web. It uses a map interface with standard zoom in/out functionality. Metadata is located on the map by circular markers - each marker within the area of interest (changed interactively) is displayed in the list on the right-hand side. The user can click on one of the data sets in the list, then choose one of the seven metadata buttons (corresponding with the FGDC metadata categories) on the top row to display the required information on a linked page.

The dialogue query template used pollution discharge on the Fal Estuary, South Cornwall for its case study (fig. 3). This template simulates the workings of an expert system (Moore *et al.*, 1998) with a Visual Basic interface. It engages the user in dialogue through a series of constructed queries to define search parameters. The system recognizes when facets of search are missing (*e.g.* specific location, time) and extrapolates search based on information submitted. It then retrieves and displays metadata that meets the search.

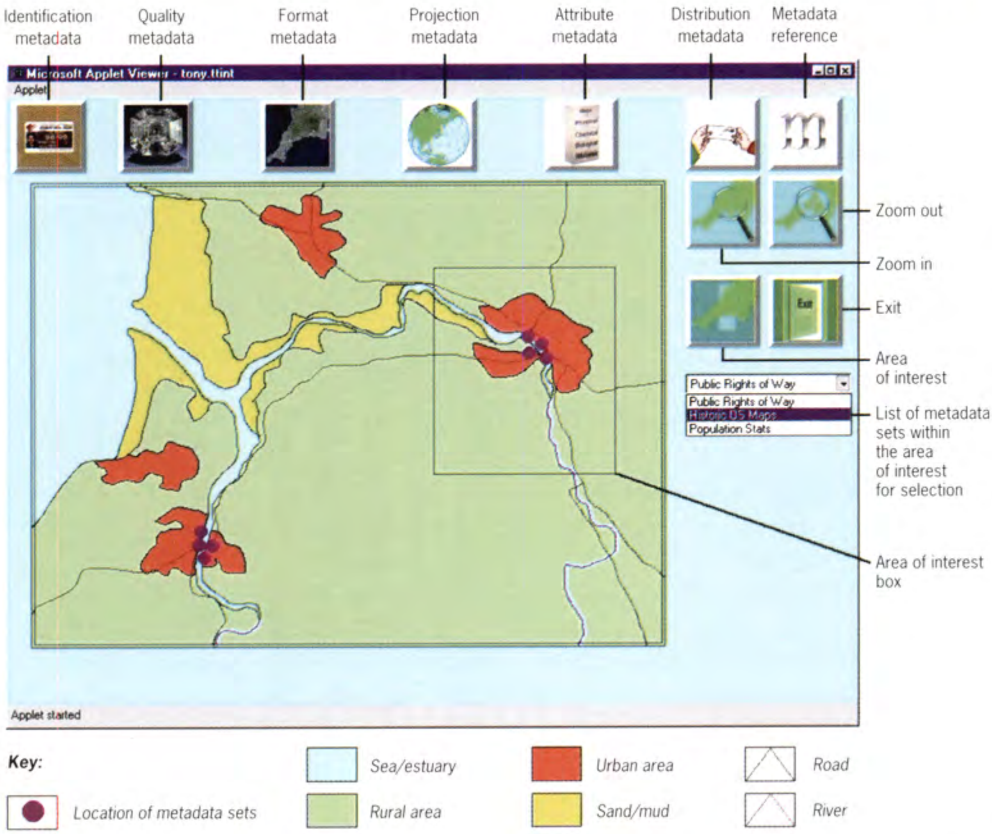


Figure 2
The geographical query template.

For the list or gazetteer query template (fig. 4), the case study was port and urban development on the Tamar Estuary, Devon. This is a Web page constructed in the style of EDMED. It uses gazetteers and lists to limit geographical, temporal and attribute search. Based on the search, the metadata is retrieved and displayed. The program is written in Visual Basic, then compiled in ActiveX giving PC-based Web capabilities.

Feedback

The outcomes of the information workshops have reinforced many of the findings borne out of the audit phase of the group's work. They have also given all participants a clearer understanding of the barriers affecting the exchange of information between different sectors, and the benefits which would arise from greater collaboration and communication between researchers and managers throughout the region.

The feedback for each template is summarised in the table. The main point to reinforce is the strong support for the geographical query template, though its shortcomings lie in not being able to handle non-spatial and temporal data. However, the dialogue and list query templates are able to do this. It would seem that a 'user-preferred' system would include features from each, or a hybrid of the three templates presented.

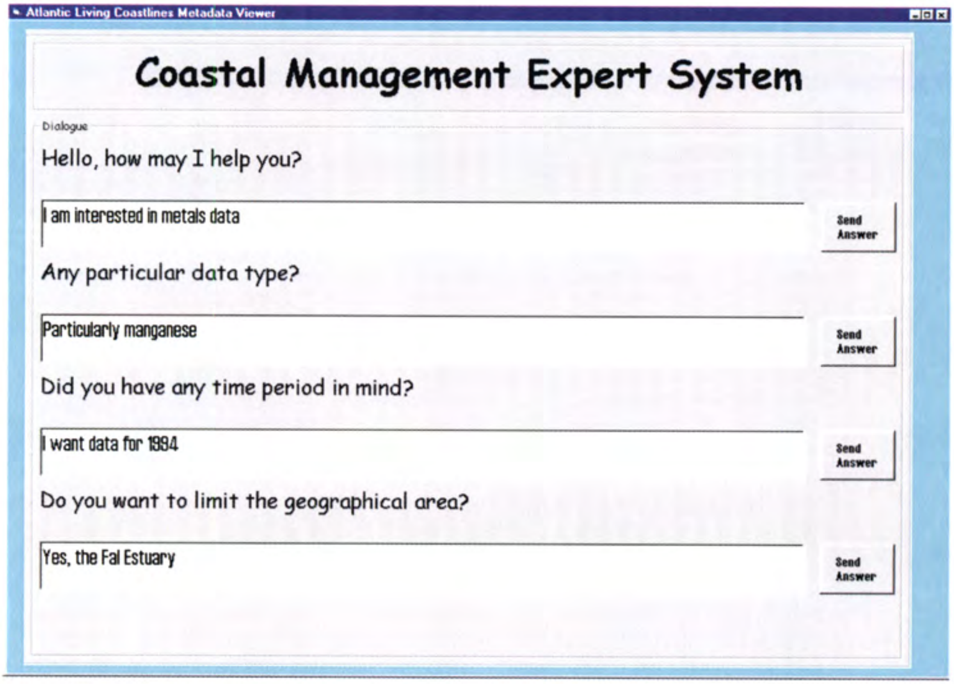


Figure 3 - The dialogue query template.

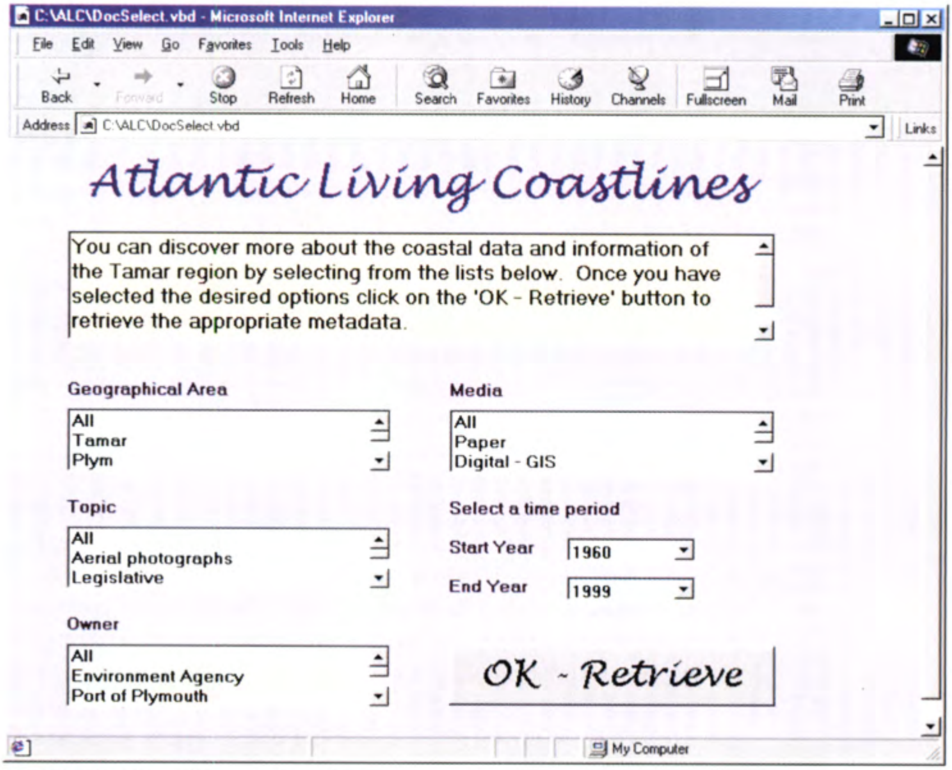


Figure 4 - The list/gazetteer query template.

Other issues touched on system usability, data availability, access and dissemination, system design, ongoing maintenance and the benefits of maintaining personal contact. There was a proposal of a coastal observatory running in parallel with the information system (which stores databases of contacts, organizations and areas of expertise), augmented by a SW regional coastal Website incorporating a newsgroup or a SW Coastal Forum.

The advantages and drawbacks of each template.

Query Type	Advantages	Drawbacks
Geographic	User-friendly (no typing)	Handling disparate scales
		Handling non-spatial and temporal metadata
	Immediate visual impact	Lack of speed
		Too much complexity
Dialogue	Flexible and simple	Slow and tedious for the experienced
	Conversational style - intuitive	Assumes user knows target metadata
	Handles non-spatial and temporal metadata	The correct key words have to be chosen for the query
List	Familiar	Constrained by the list
	Clear and simple	Slow and tedious
	Good for the IT novice	

Recommendations

An Internet-based hybrid system is proposed, for maximum and effective dissemination. The popular geographical template will be used as default, with the dialogue or list query (which will be displayed instead of the map when selected) to be used for a spatial queries. Further initiatives include:

- the lateral linkage of information through hyperlinks and keywords in the metadata output that would be subject to search;
- metadata of different spatial scales can be explored by clicking on its marker on the map to give a scale circle (or polygon if the area is precisely known);
- several levels of access effected by accounts and passwords over the Internet;
- a glossary for specialist words, accessed *via* hyperlinks or 'Tool Tip Text';
- clarifying the icons in the geographic template, colour-coding metadata sites according to theme and specifying an area of interest with a polygon;
- making the dialogue more explanatory, with use of leading questions and choices. This will reduce emphasis on the black box approach.

Suggested additional fields in the metadata output will include whether the listed data is available or not, and whether the data referred to is spatial or aspatial. Metadata output fields in general should not be set in stone, and should be modified as applicable (*e.g.* in response to the forthcoming ISO standard). Hyperlinks to Web addresses containing indices, thematic summaries, EU initiatives, environmental data and other contextual data will be enabled. These will all have a corresponding metadata entry.

Drawing from the feedback and the findings of the Demonstration Programme (EC, 1999), the development of a local coastal observatory is proposed. This will be a major point of contact for coastal data and information, providing signposts to contacts as well as facilitating guidance for known problems. The information system and Website would run alongside this social network. Two major tasks were identified for such an observatory: publicity (generating awareness of the resource; generating participation in getting stakeholder data online) and maintenance (overviewing metadata currency, quality, data interpretation and glossary building).

Conclusion

The findings of the audit, backed up by user recommendations in the seminar will feed into the construction of a demonstration CZMIS to support the overall strategy. An Internet-based hybrid metadata system was proposed to show the 'what' and 'where' of coastal data, using all the suggested modes of metadata access, and with the highlighted changes (ensuring ease of use). This would be supported by a coastal observatory to maintain a human interface with the decision makers. Three chief tasks of the observatory would be strategy (ensuring a holistic view to coastal data management), maintenance (regular updates) and publicity of coastal data, information and their access mechanisms. Through participation activities such as questionnaires, interviews and seminars, this chapter has shown what can be achieved by involving the CZMIS user in all stages of the design of such a system. This closes the gap between the decision-makers and the best technology available to help them in their day-to-day tasks. This surely means that the end system is one that is relevant and one that will be widely used in practice.

Acknowledgements

We would like to thank all people who have taken part in the audit phase and seminar, particularly the members of the Coastal Information Focus Group. We would also like to thank Brian Shipman and Aidan Winder for their helpful comments on this paper, John Marshall for his programming advice and Thomas Coty for the translation. The Atlantic Living Coastlines Project is funded by the European Union TERRA (DG XVI) programme. The views expressed in this paper are those of the authors and not those of the Atlantic Living Coastlines Project.

Bibliographic references

Association for Geographic Information (AGI), 1999. Guidelines for Geographic Information Content and Quality. AGI, London.

British Oceanographic Data Centre (BODC)., 1999. EDMED - The European Directory of Marine Environmental Data. Natural Environment Research Council, Bidston.

Busby J.R., 1999. Principles, Practices and Current Directions in Information Management - An Overview. *In:* Bridge L. (ed.). Info-Coast'99 Symposium report. CoastLink Coastal and Marine Observatory, Dover, UK and EUCC UK, Brampton, UK. 7-10.

Davos C.A., 1998. Sustaining co-operation for coastal sustainability. J. Environ. Manage., 52, 379-387.

Doody J.P., 1996. The Coastal Directories Project. *In:* Coast and seas of the United Kingdom: Region 10 - South West England - Seaton to the Roseland Peninsula. Barne J.H., Robson C.F., Kaznowska S.S., Doody J.P., Davidson N.C. & Buck A.L. (eds), Joint Nature Conservancy Committee, Peterborough.

Doody J.P., Pamplin C.F., Gilbert C., Bridge L., 1998. European Union demonstration programme on integrated management in coastal zones, Thematic Study F - Information required for Integrated Coastal Zone Management. Report to European Environment Agency, Copenhagen, Denmark.

European Commission (EC), 1999. Lessons from the European Commission's demonstration programme on Integrated Coastal Zone Management. European Communities, Luxembourg, 93 p.

Federal Geographic Data Committee (FGDC)., 1998. Content standards for digital geospatial metadata. United States Geological survey, Reston, VA.

French H.F., 1995. Environmental treaties grow in number. *In:* Vital signs: the trends that are shaping our future 1995-1996. Brown L.R., Lenssen N. & Kane H. (eds), Earthscan Publications Ltd., World-watch Institute, London, 90-91.

French P.W., 1997. Coastal and estuarine management. Routledge, New York.

Goodchild M.F., 1998. Different data sources and diverse data structures: Metadata and other solutions. *In:* Geocomputation - a primer. Longley P.A., Brooks S.M., McDonnell R. & Macmillan W. (eds), Wiley, Chichester, 61-73.

Green D.R., 1995. User-Access to Information: a priority for estuary information systems. *In:* Proc. CoastGIS'95: International symposium on GIS and computer mapping for Coastal Zone Management. Cork, 35-60.

Hooke J.M., 1988. Introduction Frameworks for Interaction. *In:* Geomorphology in environmental planning. Hooke J.M. (ed), Wiley & Sons Ltd, New York.

Moore A.B., Morris K.P., Blackwell G., Gibson S.E., Stebbing A., 1998. A expert system for Coastal Zone Management: a geomorphological case study. Mar. Pollut. Bull., 37(3-7), 361-370.

Morris K.P., Hill D.R., Moore A.B., 1999. Mapping the environment through three-dimensional space and time. *In:* Proc. Geocomputation 99, Washington DC, USA.

Ricketts P.J., 1992. Current approaches in Geographic Information Systems for Coastal Management. Mar. Pollut. Bull., 25, 82 -87.

United Nations Environment Programme (Unep), 1995. Guidelines for integrated management of coastal and marine areas. Unep Regional Seas Reports and Studies, 161.

A GIS application *via* Internet for environmental management of harbour areas. The GeoNet 4D Project, demonstrated on the Fos-Marseille zone

Didier Sauzade[(1)], Jacques Denis[(1)], Gilles Hervé[(1)], Jean-Manuel Canet [(2)]

(1) Ifremer Toulon, Zone portuaire de Brégaillon, BP 330, 83507 La Seyne-sur-Mer Cedex, France - Didier.Sauzade@ifremer.fr

(2) France Telecom Expertel, 6 impasse Bonne Nouvelle, BP 806, 75470 Paris Cedex 10 France

Résumé

La gestion environnementale des zones côtières demande un niveau de communication élevé entre les différents acteurs qui y participent. Une grande part de cette communication porte sur des informations à référence spatiale. Il a été montré que les SIG sont des outils très efficaces pour la gestion de la zone côtière. Cependant, la diffusion des SIG est freinée par le coût élevé de ces systèmes. De plus, les systèmes et les bases de données développés sont rarement facilement compatibles. La diffusion d'applications SIG par Internet, rendue récemment possible grâce à des technologies émergeantes, permet de contourner ces limitations, mais au prix d'autres contraintes qui restent à évaluer avant une mise en œuvre à grande échelle. Le projet européen GeoNet 4D (DG III - Esprit), coordonné par une filiale de France Telecom, a consisté à construire une solution informatique, faisant notamment appel au langage Java, permettant à de multiples utilisateurs d'échanger de façon interactive des informations cartographiques en utilisant les technologies des réseaux grand public. Les outils informatiques développés ont été évalués au cours de trois démonstrations concernant les zones portuaires de Fos-Marseille (France), de Santander (Espagne) et de Naples (Italie). La démonstration de Fos-Marseille a été conduite sur le thème de l'élaboration, de l'utilisation en cas de crise et de la mise à jour d'un atlas de la sensibilité aux pollutions, en impliquant les acteurs concernés.

Les spécifications de base du système, la solution informatique, ainsi que la base de données géographiques construite pour la démonstration, sont présentées. Les résultats de l'évaluation (réseaux, informatique, réactions des utilisateurs...) établis à l'issue de la démonstration sont discutés.

Abstract

Environmental coastal zone management requires a high level of communication between actors. A large part of this communication deals with spatially referenced information. The efficiency of GIS as a tool for coastal zone management has been well established. However, its widespread use is limited by the high cost of such systems. Moreover, it is difficult to make developed systems and databases compatible. Distribution of GIS applications using the Internet protocol is now possible, thanks to new emerging technologies, but it induces other constraints, which must be assessed before large scale implementation. The GeoNet 4D project (DG III - Esprit) consortium, co-ordinated by a subsidiary of France Telecom, has developed a Java-based software prototype enabling several users to retrieve advanced GIS information through intranet/Internet networks. This solution was evaluated in three field trials in the harbour areas of Fos-Marseille (France), Santander (Spain) and Napoli (Italy). The purpose of the Fos-Marseilles field trial was to build, operate and update a coastal pollution sensitivity atlas for the harbour area, involving all stakeholders.

This paper presents the system specifications, the software and the geographic database built for the demonstration. Results of the field trial evaluation in terms of network capacity, software performances and user acceptance are discussed.

Introduction

Integrated coastal zone management (ICZM) requires a high level of communication between the actors involved (Denis *et al.*, 1997). The ICZM process requires that information and collaboration be truly interrelated (UE, 1999). The current situation of information and knowledge management for the implementation of ICZM is of great importance in removing major barriers to effective data, information and knowledge flow between the provider and end-user communities (Gesamp, 1996). A great deal of this communication deals with spatially referenced information. In the framework of the European Demonstration Program on ICZM, a study was made on technology's role and use with respect to ICZM (Capobianco *et al.*, 1998). Geographic information systems (GIS) appear most likely to play a role in this domain (Biliana-Cicin & Knecht, 1998). However, to date, dissemination of GIS has been limited by the high cost of use and ownership of a GIS application during its life cycle. It is now well known that the price of a GIS (hardware and software) is not the most important cost factor. Issues such as usability, learning and training cost, support and data greatly influence the total cost of a GIS application. One solution is to share the cost between organizations involved in management of the same coastal zone. Distribution of GIS applications using the Internet protocol is now possible, thanks to new emerging technologies, but induces some constraints that must be assessed prior to large scale implementation.

The GeoNet 4D Project

GeoNet 4D is a 30-month project in the framework of the Esprit Programme of the European Commission's DG III. It aims at demonstrating and evaluating the usefulness of several combined advanced technologies (GIS, Internet/intranet & Multimedia) for European users. GeoNet 4D primarily focuses on applications for environmental and commercial activities in port and coastal areas.
The GeoNet 4D consortium has developed a prototype called "GeoPro". A client equipped with a PC and a Web browser can retrieve, annotate or, to some extent, modify advanced geographic information from a server *via* an intranet or Internet connection. Figure 1 illustrates the GeoNet 4D system principle.

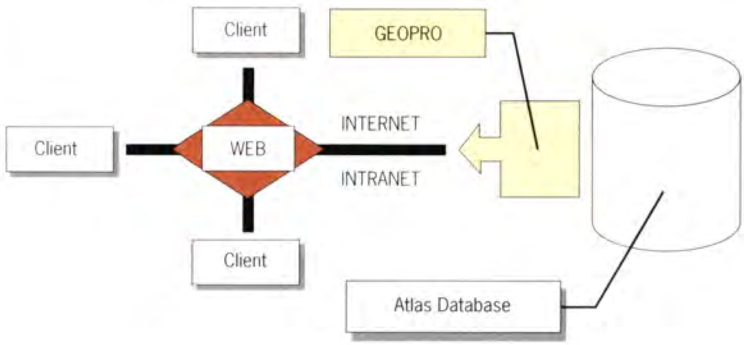


Figure 1
GeoNet 4D system principle.

GeoPro software combines universal and widely used tools such as Java and requires geographic data. It has been developed in close co-operation with ESRI Germany, a subsidiary of ESRI, the leading GIS provider worldwide.
Several domains of applications were identified for the demonstration and evaluation of GeoPro:
- updating and using environmental coastal information;
- preparing pollution response actions;
- planning port activities, especially dredging;
- stimulating commercial port activities, by facilitating access to information.

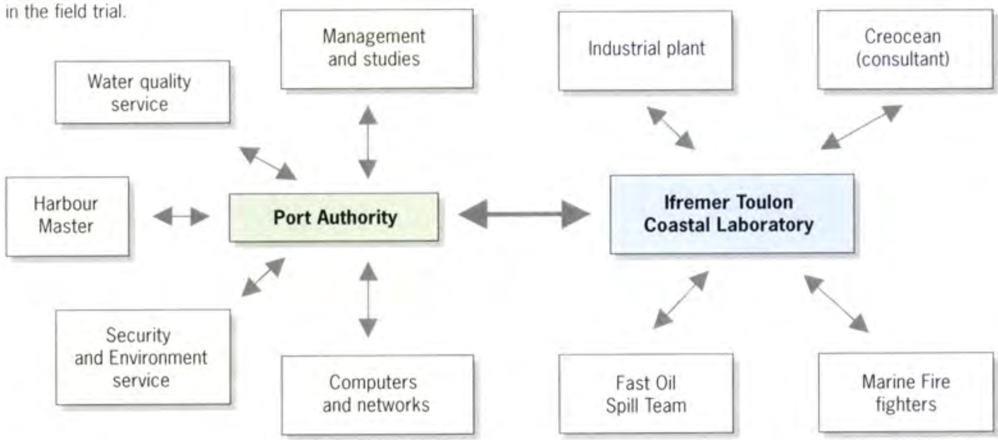
The field trial in the Fos-Marseille area focused on the update and operation of a coastal sensitivity atlas devoted to preparing response actions in case of accidental pollution.

The Fos-Marseille field trials

The principle was to use a Geographic Information System to perform exchanges of georeferenced data between actors concerned by environmental management in the Fos-Marseille port area: various port

Authority services, industrial firms, organizations in charge of marine pollution response, relevant administrations, scientific organizations and consultants specialized in pollution impact assessment (fig. 2).

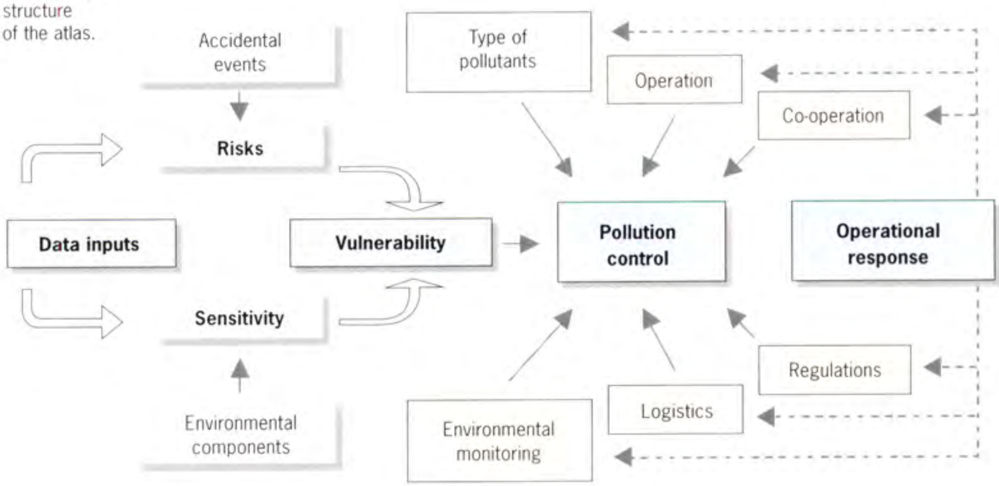
Figure 2
Actors involved
in the field trial.



The atlas

The scenario was to update and operate an atlas for preparedness and response to accidental marine pollution in the port area. The methodological structure of this atlas is shown in figure 3.

Figure 3
Methodological
structure
of the atlas.



Vulnerability is defined by cross analysis of two spatial characteristics: environmental sensitivity and risk of pollution. The atlas comprises several main themes in relation with the field trial scenario.

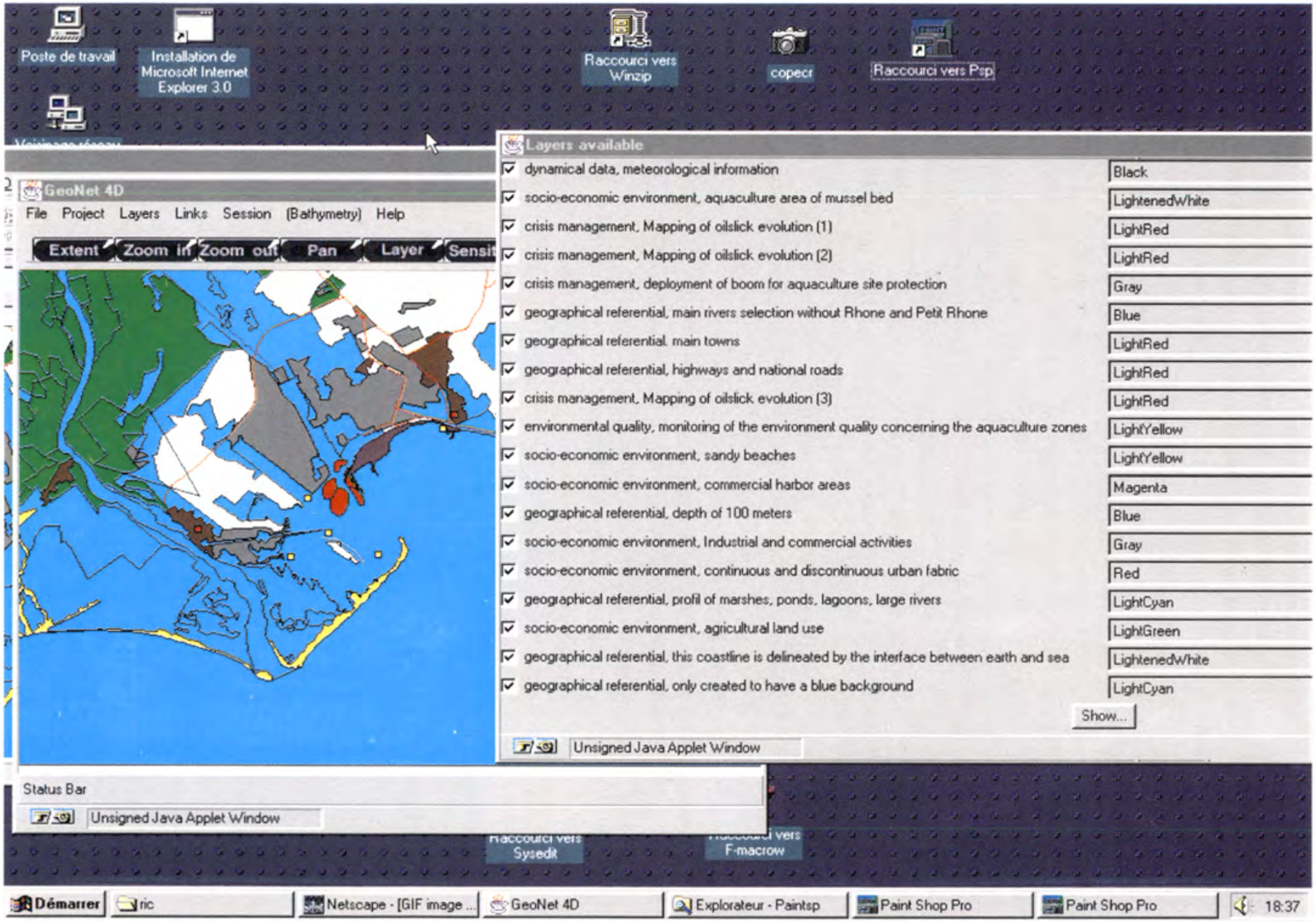


Figure 4 - Atlas GeoPro interface.

The GIS-Dataset

Basically, the GIS-Dataset used for the Fos-Marseille field trials has been built using data falling under several main themes: natural (bio-physical) and human (socio-economic) environment, coastal monitoring (quality) and management (protection), risk analysis studies (drifting oil slicks), regulations (uses, constraints), pollution control (strategy) and response (equipment and teams).

All this information has been geo-referenced and implemented in a specific GIS application structured around more than ten main themes, each composed of several theme-based maps, as shown in the following example:

- main theme: socio-economic environment;
- theme-based maps: sandy beaches, merchant harbours, industrial settlements, agricultural land use, etc.;

From the GeoPro interface, every map listed in the atlas can be selected and displayed (fig. 4).

The clients can access various data such as maps, metadata, images, tables and texts. The system allows the client to perform the following functions:

- create, add and save new themes;
- create maps by combining several themes;
- annotate a map by drawing on a theme (graffiti);
- print every mapped theme.

Scenario principle

In accordance with the high ecological and economic sensitivity of the port area and the real risks of pollution, this scenario was based on the simulation of an accident (fig. 5).

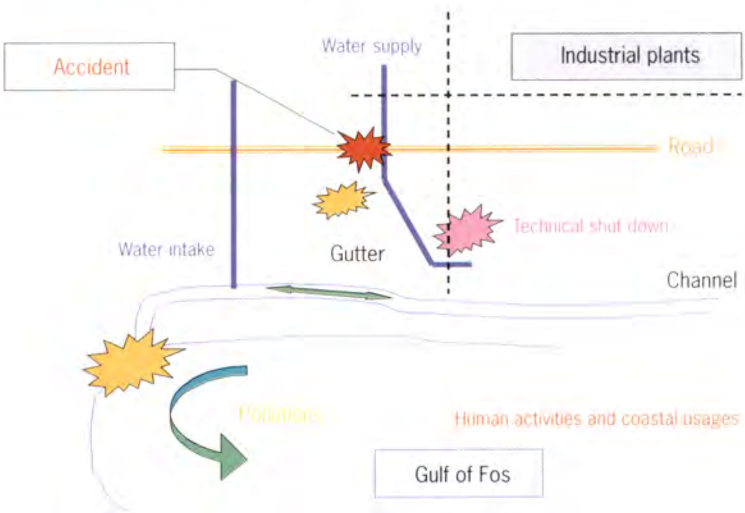


Figure 5
The scenario simulating an accidental pollution in the port area.

The pollution is due to a tanker lorry accident causing spillage of 30 m^3 of heavy fuel oil. The accident occurs on a road, the fuel slick flows into a gutter then through a canal to a shipping channel, which comes out to the open waters of the gulf of Fos.

Evaluation

To evaluate their satisfaction level regarding both GeoPro and the application demonstrated during the field trials, users participating in the exercise were interviewed face to face, using an open questionnaire. The conclusions were as follows:

• The GeoPro software proved to be easy to use after a short training period;

• The GeoPro client software was generally found to answer the main technical functionalities expected from it:

- access cartographic representation of data (users rated access to atlas information as good),
- select different levels of details (good rating by users),
- select different graphical layers (good rating by users),
- access to remote databases (integration appreciated by users),
- access to information coming from more than one source (moderate rating),
- simultaneous access to information with other users (was not fully tested over the period, could be constrained by available network bandwidth),
- modify geographical information at a distance (graffiti tool performances were found too limited at present);

• Improvement was recommended for the graphical performances, especially by users accustomed to full GIS systems;

• The functionalities of the GeoPro client software generally fulfilled users' application expectations;

• The general use of the client software was rated as too slow for use in operational conditions, especially for crisis management (access to server alone was rated as fair to poor depending on network bandwidth availability);

• The users regretted that the client software ran only with a Netscape browser, since the majority of them (port Authorities of Marseille, industrial plant…) were using Microsoft's Internet Explorer browser by default.

Conclusion

In conclusion, the main question focuses on the perspectives for exploiting such a system. It is accepted that it can play a relevant role in ICZM, thanks to information exchange capacities providing decision making support. This specific domain of ICZM involves various information processing such as sensitivity analysis, emergency planning, habitat evaluation, pollution monitoring and impact assessment, etc. (Unesco, 1997). It also involves multiple, geographically scattered decision centres with conflicting interests.

A GIS-based Web system able to satisfy such requirements would be software with the following features: client-server implementation, with current GeoPro functionalities as its core, making it possible to update an electronic coastal sensitivity atlas or add new themes, create maps with several themes, save new themes and maps, print maps and to work collaboratively on maps at a distance over a network.

This system can provide an integrated service for data management and offer a shared tool for environmental management. What is more, it could contribute to the development of networks in the CZM context and on the data exchange market in Europe.

Bibliographic references

Biliana-Cicin R., Knecht W., 1998. Integrated coastal and ocean management, concepts and practices. Unesco, Island press, 517 p.

Capobianco M., Gasparoni F., Bozzo G.M., 1998. Role and use of technologies in relation to integrated coastal zone management. Proc. Oceans' 98, Nice, France. IEEE, Piscataway, USA.

Denis J., Thébaud O., François A., 1997. Étude de pré-faisabilité d'un système d'information et d'aide à la décision. Rapport de mission PRE/COI, Ifremer Toulon.

Gesamp, 1996. The contributions of science to integrated coastal management. Reports and studies, 61.

UE, 1999. Vers une stratégie européenne d'aménagement intégré des zones côtières (AIZC), principes généraux et options politiques. Programme de démonstration de l'UE pour l'aménagement intégré des zones côtières 1997-1999. Lessons from the european commission's demonstration programme on integrated coastal zone management (ICZM). Demonstration programme on integrated management in coastal zones 1997-1999.

Unesco, 1997. Guide méthodologique d'aide à la gestion intégrée de la zone côtière. Commission océanographique intergouvernementale, série manuels et guides, 36.

Le centre Saint-Laurent et le programme SLV 2000 : pour la sauvegarde du fleuve Saint-Laurent

Marcel Houle

Centre Saint-Laurent, Environnement Canada, 105 rue McGill, 7e étage, Montréal (Québec), Canada, H2Y 2E7 - marcel.houle@ec.gc.ca

Résumé

Le centre Saint-Laurent (CSL) est un centre de recherche et de diffusion de connaissances scientifiques créé en 1988 dans le cadre du plan d'action Saint-Laurent, un programme fédéral-provincial voué à la protection, à la restauration et à la mise en valeur du fleuve Saint-Laurent. L'un des volets de ce plan d'action mise sur l'implication des communautés riveraines dans l'atteinte de ces objectifs. Le programme Zones d'intervention prioritaire (ZIP) a permis de dresser des bilans environnementaux à l'échelle locale destinés à orienter les interventions futures des communautés riveraines quant à la protection et à la mise en valeur du fleuve Saint-Laurent. Ces communautés s'impliqueront par l'établissement de Plans d'action et de réhabilitation écologique (Pare). Un aperçu de cette démarche de partenariat et de concertation locale est présenté ici. Par ses différents projets de recherche, le CSL a accumulé un corpus de données environnementales sur le fleuve Saint-Laurent. Un projet de système d'information à références spatiales qui vise à répondre aux besoins d'intégration de données et de diffusion d'information et s'appuie sur les technologies de la géomatique et de l'Internet, est présenté en conclusion de cet article.

Abstract

The St. Lawrence Centre (SLC) is a scientific research and information centre created in 1988 as part of the St. Lawrence Action Plan, a federal-provincial environmental program to protect, restore and enhance the St. Lawrence River. Under the Priority Intervention Zones Program, local environmental assessment reports are produced to guide future initiatives in the achievement of these objectives in riverside communities. The communities use these reports to establish ecological rehabilitation action plans (ERAPs) in their areas. The first part of the paper will look at how this cooperative partnership functions. The latter part of the paper will focus on a recent initiative of the SLC to manage the wealth of environmental data it has amassed on the St. Lawrence River. This spatially-referenced information system is based on geomatics and Internet technology, and is designed to integrate and disseminate all the data resulting from SLC research projects.

Saint-Laurent Vision 2000 : un plan d'action basé sur le partenariat

En 1988, un vaste programme environnemental quinquennal a été mis sur pied pour la restauration, la protection et la mise en valeur du fleuve Saint-Laurent : le plan d'action Saint-Laurent (PASL). Ce programme est le fruit d'un partenariat impliquant plusieurs ministères des gouvernements du Canada et du Québec ainsi que des organismes non gouvernementaux. Les phases ultérieures du PASL ont donné naissance au plan d'action Saint-Laurent Vision 2000 (SLV 2000), actuellement dans sa phase III (1998-2003).

Dans une perspective de développement durable et un souci d'assurer une continuité aux interventions des deux premières phases, la phase III du plan d'action SLV 2000 (Environnement Canada, 1999) vise trois grands objectifs :

- la protection de la santé de l'écosystème ;
- la protection de la santé humaine ;
- l'implication des communautés riveraines afin de favoriser l'accessibilité et le recouvrement des usages du Saint-Laurent.

Ces grands objectifs s'articulent autour de six grands domaines d'activités où des résultats tangibles sont attendus et résumés dans le tableau. Le budget total de la phase III du plan d'action SLV 2000 s'établit à 239,2 M $, ce qui en fait l'un des principaux plans d'action environnementale au Canada.

Le centre Saint-Laurent : rôle et mission

Le centre Saint-Laurent (CSL), situé à Montréal (Québec, Canada), est un centre de recherche et de diffusion d'informations scientifiques mis sur pied en 1988 par Environnement Canada, d'abord pour mettre en place et coordonner la première phase du PASL. De 1988 à 1993, environ 60 % des activités scientifiques et techniques de ce plan d'action, menées en collaboration avec de nombreux partenaires, étaient sous la responsabilité du CSL (Centre Saint-Laurent, 1995). C'est pendant cette période et la phase suivante du plan que s'est graduellement constituée l'équipe de chercheurs et de spécialistes de diverses disciplines formant aujourd'hui l'expertise du CSL vouée à l'étude et à la protection de l'écosystème fluvial du Saint-Laurent.

Dans la phase III, la mission générale du CSL s'énonce comme suit : *en s'appuyant sur la science et l'intégration des connaissances, prendre en compte les dimensions écosystémiques dans la gestion intégrée du Saint-Laurent, par rapport aux intérêts environnementaux, socio-économiques et communautaires.*

Pour 1998-2003, les activités du CSL s'articuleront donc autour de cinq grands axes d'intervention :

- impacts des fluctuations des débits-niveaux d'eau du Saint-Laurent ;
- suivi de l'état du Saint-Laurent ;
- intégration des connaissances et liens entre gestionnaires, partenaires et citoyens ;
- liens systémiques Grands Lacs - Saint-Laurent ;
- soutien aux programmes d'Environnement Canada.

Domaines d'activités du plan d'action SLV 2000.

Domaines d'activités	Exemples de résultats attendus (liste non exhaustive)
Implication communautaire	• Appui à la concertation de 14 communautés riveraines regroupées en Zones d'intervention prioritaire (ZIP) autour d'enjeux environnementaux locaux. • Soutenir la mise en œuvre de 150 projets communautaires issus des communautés locales en vue de faciliter l'accessibilité et le recouvrement des usages du Saint-Laurent. • Fournir un soutien scientifique et technique aux comités ZIP.
Agriculture	• Réduction de l'utilisation des pesticides et suivi environnemental. • Valider un indicateur sur les risques de contamination des eaux de surface par le phosphore. • Procéder au contrôle et à l'inspection dans le domaine de l'assainissement agricole.
Industriel et urbain	• Poursuite des objectifs de réduction des rejets liquides toxiques de certains secteurs industriels prioritaires (projets de prévention, soutien technique et développement technologique, contrôle et inspection). • Évaluer la toxicité des effluents de trois grandes communautés urbaines et de neuf autres municipalités afin d'appuyer les mesures de correction.
Santé humaine	• Réduction de l'exposition de la population à des risques environnementaux (pollution microbiologique et chimique des eaux de surface, consommation de produits aquatiques contaminés).
Navigation	• Développer et mettre en œuvre une stratégie assurant une gestion de la navigation soucieuse du développement durable sur le Saint-Laurent. • Suivi environnemental des activités de dragage. • Protection des berges du fleuve contre l'érosion causée par la navigation.
Biodiversité	• Protection d'espèces fauniques et floristiques en difficulté. • Protection de 120 000 ha de milieux naturels. • Plans de gestion et de conservation de milieux sensibles. • Évaluation des impacts des variations des niveaux d'eau sur les écosytèmes et les usages du Saint-Laurent. • Fournir des prévisions et des analyses sur l'état du Saint-Laurent par la mise en place d'un système de suivi intégré.

Remarque : pour un aperçu de l'ensemble des activités prévues, consulter le site Internet SLV 2000 (*www.slv2000.qc.ec.gc.ca*).

L'implication des communautés riveraines : le programme Zones d'intervention prioritaire

Dès la première phase du Plan d'action Saint-Laurent, l'importance accordée à l'implication des communautés riveraines dans l'atteinte de ses objectifs a été reconnue. En 1990, le programme Zones d'intervention prioritaire (ZIP) a été mis en place afin de favoriser les interventions locales en matière de protection des écosystèmes du fleuve Saint-Laurent et de ses principaux affluents. Cette orientation s'est vue confirmée sous le volet Implication communautaire des phases II et III du plan d'action SLV 2000.

L'objectif global du programme ZIP s'énonce comme suit : *appuyer la participation des citoyens dans la définition des priorités et dans la mise en œuvre d'actions locales en matière de conservation, de restauration et de mise en valeur du fleuve Saint-Laurent et de la rivière Saguenay.*

Une structure de partenariat ainsi qu'un processus de concertation et de consultation des communautés riveraines ont donc été mis en place. Plusieurs ministères fédéraux et provinciaux sont impliqués ainsi qu'un organisme non gouvernemental, Stratégies Saint-Laurent (SSL), qui assure le lien avec les comités ZIP locaux représentant les communautés locales. Un comité de concertation Implication communautaire est coprésidé par un représentant de chacun des deux gouvernements et de SSL afin de travailler conjointement à la mise en œuvre de ce volet du plan d'action SLV 2000.

Du bilan environnemental à l'intervention locale : les étapes de réalisation du programme ZIP

Pour chacun des secteurs d'étude, le programme ZIP comprend trois grandes étapes :
- la production d'un bilan environnemental ;
- la phase de consultation et de concertation locales ;
- l'établissement des plans d'action locaux.

Le processus global est illustré à la figure 1 et les trois phases sont décrites dans les sections qui suivent.

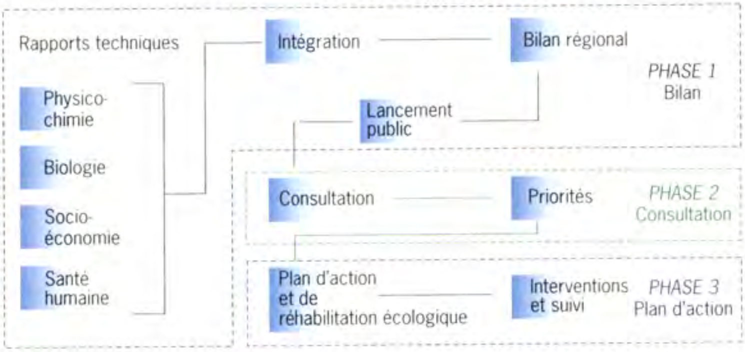


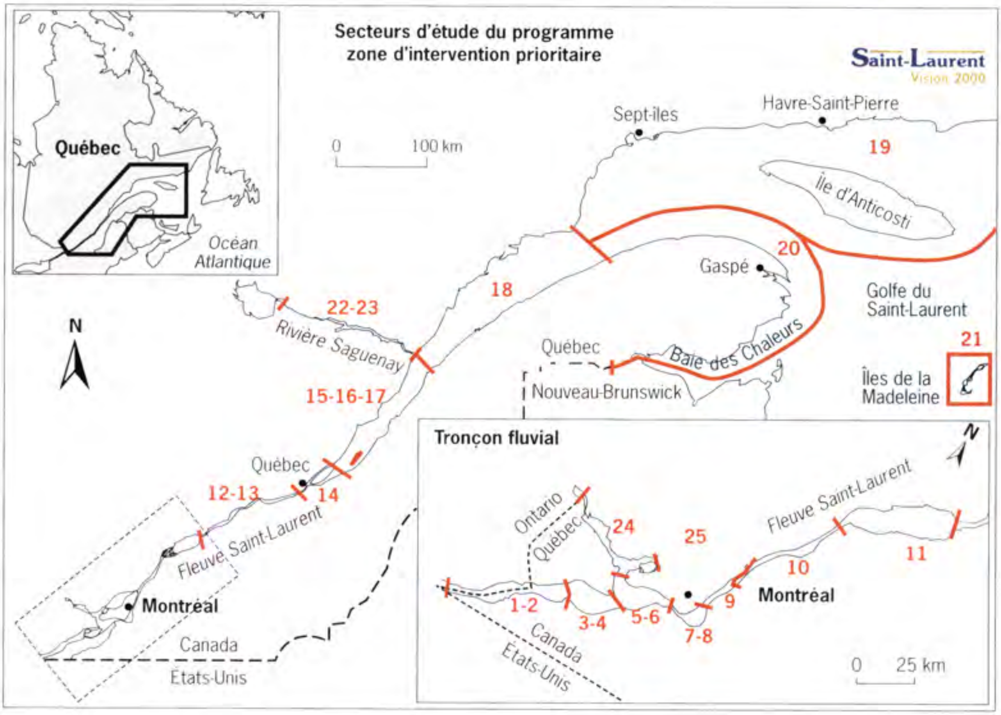
Figure 1
Étapes de réalisation du programme ZIP.

La phase du bilan environnemental régional

Réalisé conjointement par le centre Saint-Laurent et ses autres partenaires fédéraux et provinciaux, le bilan environnemental prend la forme d'une série de quatre rapports techniques et d'un document de synthèse, le bilan régional. Ces bilans se rapportent à des secteurs géographiques bien définis, les zones d'intervention prioritaire, regroupées en quatorze secteurs d'étude et couvrant l'ensemble du fleuve Saint-Laurent, incluant l'estuaire et le golfe, représentés à la figure 2.

Alors que les rapports techniques dressent un portrait analytique exhaustif et actualisé des différentes composantes de l'écosystème fluvial touchant le milieu aquatique (eau et sédiments), la faune et la flore aquatiques et riveraines, les habitats, l'occupation des rives, les usages de l'eau et les problématiques liées à la santé humaine, le bilan régional tente de synthétiser cette masse d'information enfin d'en dégager les principaux enjeux environnementaux qui seront repris lors de la consultation à l'étape suivante. Cette démarche de collecte d'informations à l'échelle locale et basée sur une méthode uniforme est une première pour l'ensemble du fleuve Saint-Laurent. La méthode d'intégration de l'information a été documentée dans Burton (1991).

Figure 2
Secteurs d'étude
du programme ZIP.



La phase de consultation

La consultation des communautés riveraines prend la forme de colloques organisés par les comités ZIP locaux, actuellement au nombre de douze, et répartis dans presque tous les secteurs géographiques du fleuve et du golfe. Les territoires respectifs couverts par les différents comités ZIP correspondent approximativement au découpage des secteurs d'étude décrits précédemment, avec des variantes découlant d'intérêts locaux. Il reste encore toutefois certains secteurs non couverts, en particulier dans les estuaires moyen et maritime du fleuve.

Après la présentation du bilan environnemental par les représentants gouvernementaux, des ateliers de travail sont constitués afin d'identifier des enjeux spécifiques et des priorités d'intervention qui guideront la préparation du plan d'action futur. Cet exercice de concertation à l'échelle locale constitue l'une des particularités originales du programme ZIP.

La phase du plan d'action

Les priorités identifiées à l'étape précédente se traduisent par la préparation d'un Plan d'action et de réhabilitation écologique (Pare). Le Pare est élaboré par le comité ZIP local, en concertation avec les intervenants intéressés. Il énonce une série de mesures et de projets concrets en réponse aux priorités, enjeux et problématiques environnementales identifiés à l'étape de consultation. Un Pare constitue donc un véritable plan d'action à l'échelle locale, identifiant pour chaque projet retenu les objectifs spécifiques, les résultats attendus, les partenaires impliqués, les échéanciers de réalisation et les coûts estimés. Les étapes suivantes consistent à recourir aux programmes de financement disponibles pour mettre en œuvre les plans d'action et à effectuer un suivi des résultats. Les rôles et responsabilités de chacun des partenaires impliqués sont résumés sur le site Web du plan d'action SLV 2000 (*www.slv2000.qc.ec.gc.ca*).

Un bilan du programme ZIP

À ce jour, une série de quatorze bilans environnementaux régionaux ont été produits, treize consultations publiques ont été tenues par onze comités ZIP, et onze Pare ont été produits. Dans la phase II de SLV 2000 (1993-1998), 90 projets environnementaux issus des Pare ont été complétés, nécessitant des budgets de 852,000 $ provenant de source locale et 920,000 $ de divers programmes gouvernementaux. Voici une liste non exhaustive des problématiques environnementales abordées lors des consultations publiques tenues par les comités ZIP :

- protection, restauration, conservation et mise en valeur des habitats fauniques et des paysages ;
- contrôle de la pollution (industrielle, municipale, agricole) ;
- qualité de l'eau potable et contrôle des installations septiques ;
- restauration de sites contaminés ;
- risques pour la santé humaine (contamination des poissons, qualité de l'eau pour la baignade et autres activités nautiques) ;
- contrôle de la navigation et gestion des niveaux d'eau ;
- éducation et sensibilisation.

Le site Internet du plan d'action SLV 2000 présente l'information la plus récente sur le programme ZIP ainsi que des exemples d'interventions entreprises par les communautés riveraines.

Perspectives

Le succès remporté par le programme ZIP a incité les gouvernements à accentuer leur soutien aux communautés riveraines dans la phase III de SLV 2000 (1998-2003), particulièrement pour la mise en œuvre des plans d'action locaux présentés par les comités ZIP. À cet effet, un budget global de 7 M $ est voué au programme Interactions communautaires, destiné spécifiquement à supporter financièrement et techniquement différents projets d'intervention environnementale issus des Pare ou des communautés riveraines (un objectif de 150 projets est visé).

De plus, le dynamisme des communautés riveraines fait en sorte que le nombre de comités ZIP est appelé à croître dans les prochaines années (deux comités créés en 1999 et deux autres prévus en l'an 2000) ; de nouvelles consultations publiques sont à prévoir et de nouveaux plans d'action et de réhabilitation écologique verront le jour. Le rôle du centre Saint-Laurent et de ses autres partenaires gouvernementaux dans le support au programme ZIP va donc se poursuivre, notamment dans les activités de diffusion d'informations et de données et, de plus en plus, dans des activités de soutien technique et scientifique auprès des collectivités locales.

Vers un système d'information à références spatiales pour l'accès aux bases de données environnementales du centre Saint-Laurent

Le projet Système d'information à références spatiales (Sirs) s'inscrit dans un objectif global qui est de favoriser l'accès à l'information environnementale relative au fleuve Saint-Laurent. La masse imposante de données accumulées à ce jour ainsi que l'acquisition des nouvelles données prévues dans la phase III du plan d'action SLV 2000 nécessitent de nouveaux outils afin de faciliter l'intégration de cette information et son accès auprès de divers utilisateurs.

Le projet vise ainsi à rendre accessible l'information environnementale disponible au CSL sous forme de bases de données géographiques, identifiées aussi par les termes données géospatiales ou données géoréférencées. Outre l'accès aux données, le Sirs veut permettre aussi des possibilités de requête par l'utilisation d'une interface cartographique couplée à des fonctions de visualisation et d'interrogation des données et ce, depuis les postes de travail des utilisateurs.

Le projet Sirs fait appel aux développements technologiques récents survenus dans les domaines de la géomatique, de la réseautique client-serveur et de l'Internet. Par l'intégration de ces technologies, de nouveaux outils peuvent être mis en place, d'où une plus grande facilité d'accès à l'information pour diverses clientèles. La clientèle à court terme regroupe le personnel interne (*via* l'intranet), et les partenaires directement impliqués dans les projets du CSL (*via* un extranet). À plus long terme, un accès au Sirs *via* l'Internet est aussi envisagé.

L'orientation technologique

Au départ, le système d'exploitation privilégié pour le développement et l'utilisation du Sirs demeure Microsoft Windows, soit l'environnement informatique largement répandu au CSL et auprès des utilisateurs prévus du Sirs. Après une revue des principaux systèmes actuellement offerts sur le marché et compatibles avec cet environnement, la technologie géomatique proposée par la compagnie ESRI (ArcView, MapObjects Internet Map Server) a été retenue pour le développement du Sirs, principalement pour sa très grande diffusion (technologie éprouvée, nombreuses applications existantes, échanges et partage d'information facilités), sa convivialité, sa rapidité d'implantation et son architecture ouverte.

Le logiciel ArcView GIS a été retenu comme système d'information géographique. Outre sa simplicité d'utilisation, le logiciel offre un puissant langage de programmation orienté objet permettant de personnaliser l'interface et de configurer les fonctions selon des besoins spécifiques. Une extension au logiciel, ArcView Spatial Analyst, a aussi été acquise pour effectuer des analyses spatiales plus complexes et pour l'intégration de données sous forme raster, notamment les données de télédétection.

La suite logicielle MapObjects Internet Map Server a été sélectionnée pour le développement des applications intranet et Internet. Cette suite est formée de trois composantes principales :

• **MapObjects Professionnel** : environnement de développement d'applications de type SIG, intégrant des fonctions cartographiques et de requêtes dans des bases de données ; il offre un ensemble de modules pouvant être utilisés dans un environnement de programmation orienté objet (Visual Basic, Delphi, C++, etc.) ;

• **MapObjects Internet Map Server** : ensemble d'applications assurant la gestion des requêtes entre une application-client et un serveur intranet ou Internet (applications et données) ;

• **ArcExplorer** : un navigateur Internet spécialisé (application-client) distribué gratuitement par ESRI, développé avec MapObjects et prêt à l'emploi ; il s'agit de l'outil utilisé par l'usager à partir de son poste de travail, qui lui permet d'effectuer des requêtes dans des bases de données géographiques par l'intermédiaire d'une interface cartographique, soit en mode client-serveur (mode www), soit en mode local.

Un serveur Windows NT a été acquis pour les besoins spécifiques du projet Sirs. À court terme (1999-2000), il sera utilisé pour le prototypage et l'expérimentation des logiciels sélectionnés et pour des applications intranet, limitées à certains secteurs cibles dans le cadre d'un projet pilote. Le module ArcExplorer sera l'outil privilégié pour accéder aux données qui auront été intégrées au Sirs. Pour l'horizon 2000-2003, nous envisageons le développement d'interfaces personnalisées et d'applications offrant une plus grande variété de fonctions à l'aide du module de développement MapObjects, ainsi que l'ouverture sur Internet.

Architecture générale

La figure 3 illustre l'architecture générale proposée pour la première phase de développement du Sirs, basée sur l'utilisation du navigateur ArcExplorer. Le cheminement des données s'effectue ainsi :

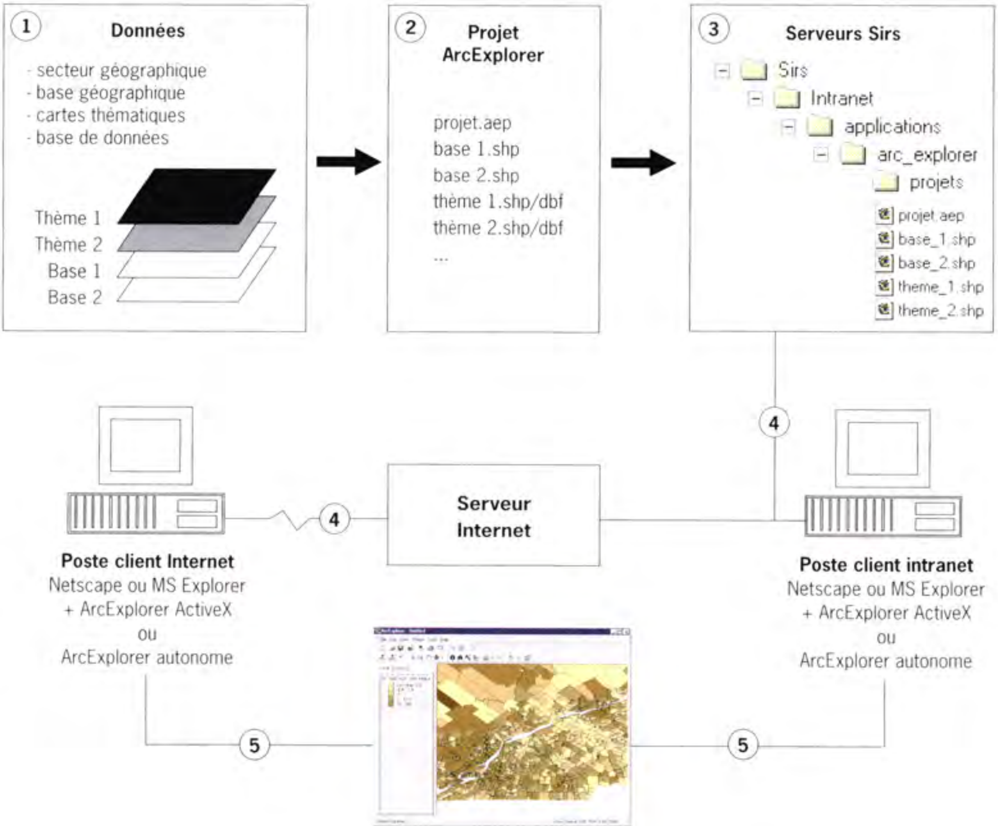
• La composante de base du système, à savoir les bases de données géographiques sera intégrée dans le SIG ArcView, sous forme de couches thématiques, pouvant être reliées à des bases de données externes. Dans la terminologie ArcView, une base de données géographiques correspond à un **thème**. Un **thème** est généralement associé à un type d'entité géographique dont la représentation graphique peut correspondre à un point, une ligne ou un polygone selon sa nature, son étendue spatiale et l'échelle cartographique utilisée.

• Un **projet** ArcExplorer est créé en regroupant un ensemble de **thèmes** (bases cartographiques et bases de données thématiques) pour un secteur géographique donné. Un **projet** se traduit par un ensemble de fichiers : fichier de projet (*.aep), bases cartographiques et bases de données thématiques (couvertures ArcView, images raster…).

• Les différents projets que l'on veut rendre accessibles sont entreposés sur le serveur Sirs. La structure d'entreposage des fichiers doit refléter les niveaux d'accès autorisés (visualisation-requête-édition-téléchargement) et les statuts de diffusion prescrits. MapObjects Internet Map Server permet de configurer différents aspects de l'accès aux données, notamment l'autorisation de télécharger ou non les fichiers de données.

• L'usager intranet se connecte au serveur Sirs par l'intermédiaire du navigateur ArcExplorer, configuré comme application autonome sur son poste de travail. Il sélectionne un ou plusieurs projets parmi ceux qui sont accessibles sur le serveur. L'usager Internet doit quant à lui se connecter à un serveur d'accès public avant de pouvoir accéder au Sirs. En raison des contraintes de mur coupe-feu, il faut envisager une duplication des données publiques du Sirs sur ce serveur afin d'en permettre l'accès *via* Internet.

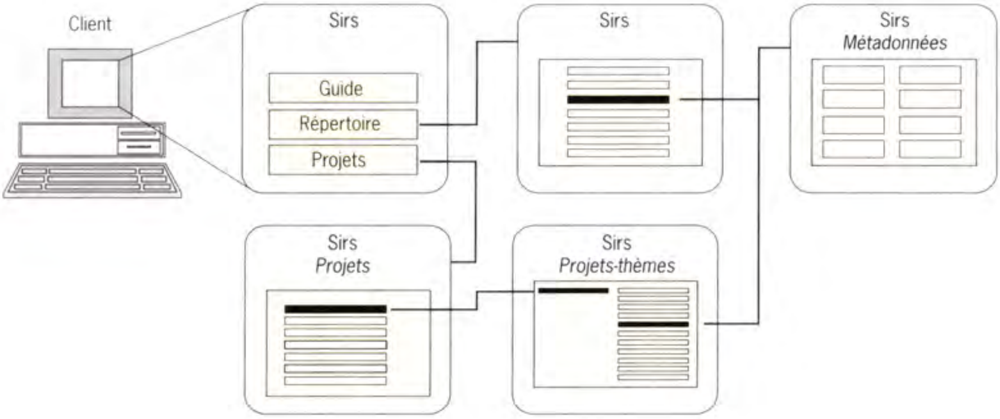
Figure 3
Architecture générale du Sirs basée sur le navigateur ArcExplorer.



• L'usager procède à ses requêtes sur les bases de données géographiques associées aux projets sélectionnés en utilisant les fonctions et menus du navigateur ArcExplorer. En mode Web, il a accès aux fonctions de navigation, de requête et de téléchargement. En mode local (si les données ont été téléchargées), il a accès à des fonctions supplémentaires : classification des données, édition de la légende, ajout ou suppression de couches, création de nouveaux projets.

À l'outil de base qu'est ArcExplorer vont s'ajouter d'autres composantes visant à faciliter l'utilisation du système, notamment les interfaces avec les usagers. Ainsi, une interface d'accès au Sirs (fig. 4), sous forme de pages HTML reliées par liens hypertextes, pourrait inclure les éléments suivants :
- un guide d'utilisation décrivant sommairement le Sirs et ses principales fonctions (une version téléchargeable au format Acrobat peut aussi être offerte) ; des liens hypertextes dirigent l'usager vers des ressources complémentaires, tels des manuels de référence ou des guides techniques plus élaborés ;
- un répertoire des bases de données géographiques intégrées au Sirs, accessible en tout temps et constamment mis à jour ; ce répertoire, aussi en format HTML, présente une liste des bases de données disponibles accompagnée d'une brève description ; un lien hypertexte permet de relier le nom d'une base de donnée à sa fiche de métadonnées ; cette dernière peut contenir des liens hypertextes vers les documents associés (rapports techniques ou scientifiques, documents de travail, etc.) entreposés au centre de documentation ;
- une liste des projets disponibles accessibles par le Sirs, porte d'entrée principale aux données ; un projet se compose d'une série de couvertures thématiques pour un secteur géographique donné ; une couverture peut être reliée à sa fiche de métadonnées par un lien hypertexte.

Figure 4
Un exemple d'interface d'accès au Sirs utilisant des liens hypertextes.



Toutefois, un usager déjà familier avec le Sirs, les données et le module ArcExplorer pourrait accéder directement aux projets et couvertures thématiques, sans passer par un site d'accueil.
Les possibilités offertes par les environnements intranet et Internet sont multiples. Au stade actuel du projet, il est trop tôt pour élaborer une architecture détaillée et complète de l'ensemble des composantes du Sirs. L'approche retenue pour le développement se veut plutôt modulaire et graduelle. À partir du schéma de base présenté précédemment seront développés et implantés les outils et interfaces qui optimiseront l'utilisation du Sirs. L'étape du prototype permettra de préciser les besoins particuliers en ce sens. En outre, les autres composantes intranet et Internet qui seront développées au CSL au cours des prochaines années influenceront également l'évolution future du Sirs.

Conclusion

Le projet Sirs fait appel à des technologies en rapide et constante évolution. Il est difficile de prévoir aujourd'hui quels seront les outils disponibles d'ici à cinq ans, qui faciliteront encore plus l'accès aux données des organisations *via* l'utilisation des réseaux locaux ou du réseau Internet.
On observe actuellement un foisonnement d'idées, d'approches et d'applications orientées vers l'accès et la diffusion de données par ces nouveaux canaux d'information que constituent les réseaux intranet, extranet et Internet. De plus, dans le domaine des données géospatiales, certains standards d'échange semblent émerger, tel Open Geographic Datastore Interface (OGDI). Ce standard, une fois accepté et implanté à une large échelle parmi la communauté des utilisateurs de la géomatique, pourrait ouvrir de nouvelles opportunités pour la diffusion et l'échange de données à l'intérieur d'un réseau virtuel d'information reliant fournisseurs et utilisateurs de données. Le CSL pourrait être appelé à participer à un tel réseau.
Par ailleurs, la majorité, sinon tous les grands producteurs de logiciels de type SIG ont un volet de développement spécifiquement destiné à un contexte d'application utilisant les technologies de l'Internet. À court terme toutefois, et pour répondre à des besoins d'analyse spatiale, le recours aux logiciels spécialisés sur stations de travail autonomes demeurera nécessaire car les fonctions complexes que cela suppose ne peuvent être facilement transposables dans un contexte d'utilisation intranet ou Internet (expertise requise, bande passante…).

Références bibliographiques

Burton J., 1991. L'intégration des aspects biophysiques et socio-économiques à l'échelle régionale : démarche retenue pour la préparation du document d'intégration ZIP. Centre Saint-Laurent, Environnement Canada.

Centre Saint-Laurent, 1995. De la science à l'action… Le centre Saint-Laurent. Environnement Canada, région du Québec, Conservation de l'environnement.

Environnement Canada, 1999. Site Internet du programme SLV 2000 : *www.slv2000.qc.ec.gc.ca*.

Remerciements

Je tiens à remercier Madame Yolaine Saint-Jacques, du centre Saint-Laurent, pour l'information relative au programme Zones d'intervention prioritaire.

Design of an oceanographic database

Fabrice Muller(1), Jean-Paul Donnay(1), Karien De Cauwer(2), Lucien Schwind(2), Mia Devolder(2), Serge Scory(2)

(1) Université de Liège, département de Géomatique, laboratoire Surfaces, 7 place du 20 Août, 4000 Liège, Belgique - Fabrice.Muller@ulg.ac.be

(2) Management Unit of the North Sea Mathematical Models, 100 Gulledelle, 1200 Brussels, Belgium

Abstract

The design and implementation of a marine database is a long and complex process, mainly due to the highly heterogeneous character of the data collected at sea. The present paper describes the IDOD project (Integrated and Dynamical Oceanographic Data Management) which is the core of the forthcoming Belgian Oceanographic Data Centre. Its objectives are to gather information in a uniform structure with easy access to the data using Web-based tools, to design and implement data analysis and decision support tools. The database itself will be part of a geographical information system.

This paper concentrates on the steps required to set up the data management tool. It also presents the difficulties encountered during the inventory and gathering of the various data to be taken into account.

The various steps in designing a database are considered: from the conceptual model to its physical implementation in a relational DBMS, *via* the intermediate steps of normalisation and translation of the conceptual model into a logical model.

Résumé

La conception et la mise en œuvre d'une base de données marines est un processus complexe et long en raison du caractère fortement hétérogène des données collectées en mer. L'article présente le projet IDOD (Integrated and Dynamical Oceanographic Data Management), noyau du futur Centre de données océanographiques belge. Les objectifs sont multiples : regroupement de l'information sous une structure uniformisée, facilité d'accès aux données, mise à disposition d'outils d'analyse et d'aide à la décision *via* le Web. L'ensemble de la base de données doit faire partie intégrante d'un système d'information géographique.

L'article se concentre sur les étapes nécessaires à la réalisation de l'outil de gestion des données. Il présente également l'ensemble des difficultés rencontrées pour inventorier et regrouper la multitude de données existantes.

Les différentes étapes de conception d'une base de données y sont présentées depuis le modèle conceptuel jusqu'à son implémentation physique dans un SGBD relationnel, en passant par la normalisation du modèle et sa transformation en un modèle logique.

Introduction: the IDOD project

The Integrated and Dynamical Oceanographic Data Management (IDOD) project is being carried out in the framework of the "Sustainable Management of the North Sea" programme funded by the Belgian Office for Scientific, Technical and Cultural affairs. Its purpose is to set up a national oceanographic information system, taking as its basis the measurements made by the various projects funded by the programme. The IDOD project started in 1997 and its development and tuning phase will end in December 2001. Afterwards, the tools built in the course of the project will be kept within the Management Unit of the North Sea Mathematical Models, which acts as the Belgian National Oceanographic Data Centre.

The purpose of IDOD is to establish, manage and promote a database of marine environmental data. Meanwhile, IDOD aims at ensuring a scientifically sound data flow between the data producers (laboratories performing routine monitoring, field and laboratory experiments, mathematical modellers and administrative authorities) and the end users (scientists, sea professionals, policy and decision makers, etc.). For a long time, various institutions and laboratories took oceanographic measurements, often under co-ordinated research objectives. However archiving and management of the data were rarely co-ordinated. One of the objectives is to archive and make the existing data sets available in a homogeneous way.

Three organizations are involved in the project:

- Management Unit of the North Sea Mathematical Models (MUMM);
- department of the Royal Belgian Institute for Natural Sciences;
- Laboratory SURFACES of the University of Liège;
- University Centre of Statistics of the Catholic University of Leuven (UCS).

SURFACES is responsible, together with MUMM, for the conception and physical implementation of the database and the development of the spatial analysis tools. UCS is responsible for developing the quality control and statistical analysis tools in close collaboration with MUMM and the data providers. MUMM acquires and continues inventorying the different data sets by contacting involved laboratories.

Data description

Contact with data providers

Mutual confidence and contacts between data providers and developers are of prime importance for the design of a database and data exchange. It is a long-term process. The data providers initially contacted are laboratories participating in the framework of the Sustainable Management of the North Sea programme. Several times a year, a meeting takes place with all the co-ordinators of the different projects funded within this programme. Information is given on the progress of the IDOD project and feedback is requested. A newsletter is issued two to three times a year to inform all those involved about the IDOD database developments. The papers published therein are sent with "request for comments".

For practical information on the characteristics and the transfer of data, the IDOD team contacts the data manager assigned for each project. Finally it must be noted that, in order to improve their knowledge of the data acquisition process, members of the IDOD team regularly join scientists during sampling surveys at sea.

Inventory and acquisition of data sets

The first task of the IDOD project consisted in inventorying the existence of relevant data sets. EDMED, the European Directory of Marine Environmental Datasets (which is currently being updated in the framework of the EU concerted action Sea Search, [*http://www.sea-search.net*]), was used as a starting point for this task.

Although MUMM has been collecting data at sea for years, its own data sets mainly concern contaminant concentrations in seawater. Therefore, other data sets had to be gathered to enable a description of the characteristics of all data types.

Further investigation of the data sets collected in the frame of the programme revealed the following advantages:

- they cover a wide range of disciplines;
- data providers can be contacted for more information on the characteristics of the data;
- missing meta-information can be asked for, as the projects are ongoing, resulting in an immediate impetus to laboratories for better data management and quality control.

The following strategy has been adopted: the laboratories involved are asked to submit recently collected data in the format considered appropriate by them. The IDOD team checks the availability of the data, the meta-information (date, time, position, sampling depth, methods and quality control information), expected parameters and the quality of the data set (clear description of parameter and unit, detection limit, precision, number of significant figures). During a visit to the laboratory, the missing metadata and more explanations, especially on the methodology, are asked for. The laboratories receive feedback on the screening of their data.

The inventory and acquisition of datasets is a time consuming procedure. It took several months to receive the list of parameters measured in the frame of the project from all services. When a data set is finally received, it is often far from complete with respect to all the meta-information required.

Design methodology

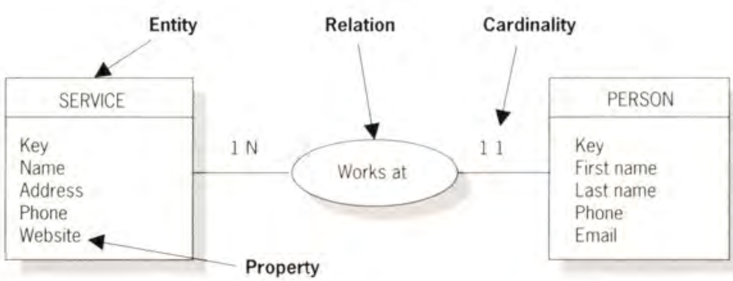
An appropriate methodology

The design of a database for a GIS requires a methodological approach to the problem. The most common scheme used to manage hybrid data sets is based on a pair of databases, one for non-spatial alphanumerical data, and another reserved for spatial or geographical data. These two data sets constitute the data aspect of the GIS. The design of a powerful GIS database must be elaborated using reliable methodology such as Mecosig/Congoo (Pantazis & Donnay, 1996). However, the lack of real topological relations in the IDOD database and the high diversity of the teams involved in the project, led to the choice of a more general design methodology such as Merise (Nanci & Espinasse, 1996).
Following the Merise guideline, the conceptual datamodel of the database is created using the Entity/Relationship formalism. This datamodel is a static representation of the information system or of all the data in the domain. It is designed with abstraction of the technical aspects of the database implementation and access techniques. It refers only to abstract objects and associations between them. The conceptual datamodel describes these objects and associations.

Conceptual datamodel and E/R formalism

The Entity/Relationship formalism is a high-level semantic design tool that is set up on three fundamental constructive concepts: the *attributes* or *properties*, their gathering into *entities* and the links or *associations* between these entities.

Figure 1
E/R formalism design.



Attribute or property

The *attribute* or *property* is the representation of an elementary or atomic datum. It is the smallest part of information used by the system with a meaning. The attribute can be single (first name, phone number, etc.) or compounded (address, date, etc.). The attribute describes the entity or the relation and exists only if it is part of an entity or a relation. An attribute is unique in a conceptual datamodel, so that it is part of only one entity or relation.

Entity

The entity represents a set of objects of the same type that are abstract or concrete. It is a group of attributes and represents only one semantic concept. The entity determines a type, a class or a group where all the elements are called the entity occurrences. To refer directly to one occurrence of an entity, the entity requires a special attribute called an *identifier* or *primary key*. One value of this identifier corresponds to one and only one occurrence of the entity. It must be invariable and can never be changed or modified until the occurrence is deleted.

Relation

The relation is a group of associations of the same type between two or more occurrences of entities of same or different types. The relation translates the words of the natural language. For example, in the figure above, the relation *"works at"* between the entities Service and Person is the translation of the sentence *"person X works at service Y"*. Contrary to an entity, a relation has no real existence. The relation is simply expressed by the implied entities. The minimum number of entities involved in a relation is two. The dimension of a relation is the number of participating entities. Like an entity, a relation can also contain some attributes.

Cardinality

For each entity-relation pair, the cardinalities are the minimum and maximum numbers of occurrences of the relation that can exist for one occurrence of the corresponding entity. The cardinality values are indicated above or on the link between the entity and the relation.

Logical datamodel

The logical level is the second step in the database design. The entities are converted into tables for a relational database. There are three kinds of relations to be considered: one to one, one to many, many to many. The first and second types of relations are converted into the logical datamodel by adding new foreign keys to the tables. The third one is more complex and requires the creation of a transition table as illustrated in figure 2. A service may participate in several campaigns, but a campaign involves at least one or more service(s).

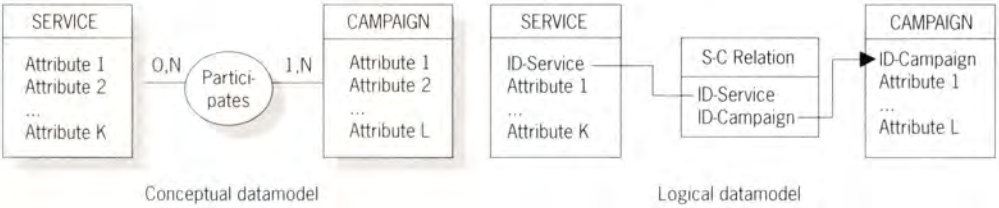


Figure 2
Example of relation.

Design of the IDOD database prototype

Data semantics

To organize the data, the different steps from collection to result have been reviewed. Figure 3 gives an overview of the resulting structure. Samples are collected in the frame of a project, during an oceanographic campaign or survey on a platform. The platform can be a research vessel, "field walking", an automatic measurement station, etc. Specification of the involved services and persons is important for both the campaign and the project. A project results in or contributes to one or more data sets and vice versa. Samples are characterized by a position, sampling depth, time and sampling method. Information on meteorology and the ecosystem (*e.g.* estuary, coastal sea) will be stored with every sample to enable the direct display of environmental circumstances.

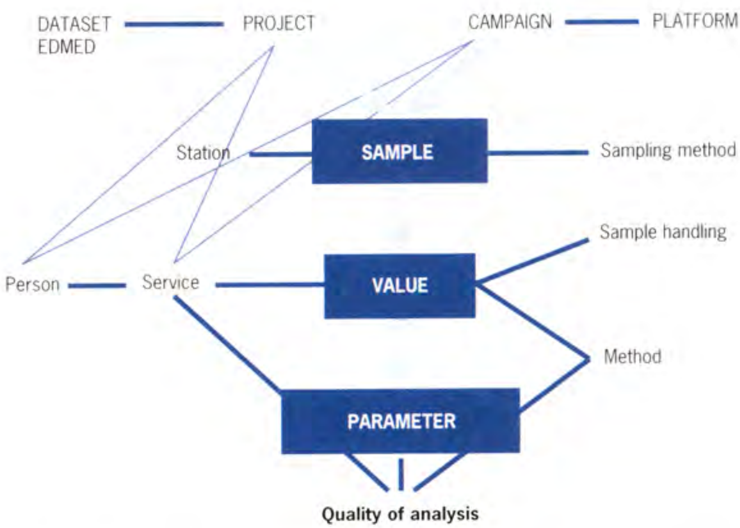


Figure 3
General structure of IDOD for data measured in seawater.

The resulting values are stored in the original units to maintain the precision. The values are accompanied by a qualifier flag indicating whether the reported value should be qualified as "less than" or "greater than", a validity flag given by the data provider or manager, and a statistical quality control flag. In order to obtain the latter, the consistency of values is checked against the statistical characteristics (like spatial continuity of data and the correlation between variables) of the results already present in the IDOD database. A flag indicates when the time reference system is not known (otherwise converted to UTC). Similarly, another flag states when the position reference system is unknown. Both flags are especially necessary for historical data.
The analysis and sample handling methods are related to the result. The detection limit, detection unit, and precision are provided for the

"analysis method" entity. All values are linked to a parameter described by a code and a full name, accompanied by the measurement unit, matrix and substrate.

To incorporate information on the quality of the analysis method, three different aspects have to be introduced: QUASIMEME intercomparison exercise codes (Topping, 1998), control chart information and inter-calibration exercises. For a given service measuring a given parameter with a given analysis method, one or more scores can be obtained during intercomparison exercise(s), and similarly for information on control chart(s) and intercalibration exercises.

Conceptual datamodel

Following the data semantics, a conceptual datamodel was developed for seawater. The DB-MAIN case tool was used for the design of the model (Hick *et al.*, 1999). Twenty-one entities and twenty-nine relations compose this model.

Some entities are linked together by more than one relation such as "project" with "person" because there is one co-ordinator for a project and many other people working on that project. The cardinalities are used to express these constraints (*e.g.*, one and only one person is co-ordinator for a project, but a person can supervise from zero to N projects). To avoid mistakes and inconsistency, the first three normal forms of the database conception rules were checked and some modifications were made to satisfy them (Kroenke & Dolan, 1988). With respect to the third normal form, the "parameter" entity was split into two new entities, "parameter" and "category" (fig. 4). Many parameters can be in the same category, and this way, it is possible to modify a category without having to browse all the parameters included in this category to apply the change. It ensures the integrity and consistency of the database.

As mentioned above, there are three types of information related to the quality of analysis to be incorporated: QUASIMEME intercomparison exercise codes, control chart information and intercalibration exercises. All these are represented in the model by use of the specialisation with the constraint "T" specifying that an occurrence of the entity is specialized into one and only one sub-entity.

Figure 4
Example of splitting one entity into two entities.

Data dictionary

The conceptual datamodel is closely linked to the data dictionary. The dictionary is the user's guide of the database with a complete description for all attributes and entities. A short example for the entity "station" is shown in figure 5.

For each attribute, the dictionary mentions the field type and format, and presents an example accompanied by a comment. When "Required" is mentioned in the "Comment" column, it means that a value is mandatory for this field.

Figure 5
Description of the entity STATION in the data dictionary of IDOD.

Database: IDOD				**Entity: STATION**	
Description: The STATION entity describes a geographical location sampled regularly					
Related entities: Non-continuous value, continuous value					
Attributes:					
Name	**Explanation**	**Type**	**Format**	**Example**	**Comment**
ID-Station	A code to identify one occurrence of the STATION entity in the database	Key			Required, unique, system-generated
Name	The name of the station	String	10	330a	Required
Start date	Date of first sampling	Date		21/11/1985	
End date	Date of last sampling	Date		07/12/1995	
Reference latitude	The latitude of the station location	Float		51.80833°	Required Decimal degrees
Reference longitude	The longitude of the station location	Float		2.80833°	Required Decimal degrees

Logical datamodel

The logical datamodel is obtained from the conceptual datamodel here above. The entities are converted to tables and some conversion rules are applied to the relations. As explained in page 128, this required adding new attributes or tables to materialise some types of relations. For the prototype, all these steps are done manually. With a case tool, they would be generated automatically.

Physical implementation

A prototype of the IDOD database was developed. DBMS Microsoft Access97 was chosen for its friendly interface. With its Open Database Connectivity (ODBC), it also offers the connection and sharing of data with many other software programs. Moreover, this DBMS was available at low cost to every partner in the project. The migration to the final DBMS (Oracle, Sybase, SQL Server, etc.) will be done easily by use of existing exportation filters. The tables and links are implemented with respect to the previously sketched logical datamodel and the cardinalities are implemented in Access97 by the property values attached to each field of the tables.

A first batch of data was entered in the prototype, using the export tables of the previous database available at MUMM. Nevertheless, extra information had to be captured, such as the different projects, campaigns, persons, etc. The latter process was particularly time-consuming. A general query has been constructed within an Access form. Microsoft Visual Basic was used to construct the SQL-code (Viescas, 1997).

Conclusion

The IDOD project aims at integrating a high diversity of oceanographic data. Good understanding of the data is a prerequisite in designing a database. Therefore, regular contacts and several discussions with the data providers were planned. Visits to the data-providing laboratories provided much descriptive information and the need for meta-information could be explained on the same occasion.
Acquiring data and all meta-information proved to be a very time-consuming process. Data providers had to be contacted several times before a dataset could be considered as complete. Consequently, it was decided to start with the development of a prototype for the concentration data measured in seawater, as a lot of information was already available at MUMM. In the resulting prototype, the values are accompanied by documentation enabling the user to assess the quality and suitability for a particular task.

Perspectives

In order to cover the whole range of data types submitted to IDOD, similar datamodels are being developed for sediment characteristics, contaminant concentrations in sediment and biota, and information on the abundance of species. It implies, for instance, that extra entities be planned to enable the storage of subsample and tissue information with the necessary attributes, *e.g.* upper and lower depth of a sediment subsample, organ weight, etc. Continuous measurements (fixed position and underway) will also be included in the database. The spatial or geographical data (like bathymetry and coastlines) will be organized in a GIS such as Intergraph Geomedia or ArcView. These data will be recorded in the internal format of the GIS software.
As they offer two important characteristics, namely their capability of simulating and anticipating processes, mathematical models are also thought to be an important source of information in the scope of the project. Adequate validation procedures will be defined and results of validated models will be incorporated into the database.
Finally, useful and scientifically sound information will be provided to a wide range of users. Special attention will be paid to derived products (maps, tables, reports, etc.) so that they meet the specific requirements and level of expertise of the various categories of users.

Acknowledgements

The IDOD project is fully sponsored by the Belgian federal Office for Scientific, Technical and Cultural affairs.

Bibliographic references

Hick J.-M., Hainaut J.-L., Englebert V., Roland D., Henrard J., 1999. Stratégies pour l'évolution des applications de bases de données relationnelles : l'approche DB-MAIN. XVII^{e} congrès Inforsid, La Garde, France, juin.

Kroenke D., Dolan K., 1988. Database processing: fundamentals, design, implementation. Science Research Associates, 687 p.

Nanci D., Espinasse B., 1996. Ingénierie des systèmes d'information Merise. Sybex, 891 p.

Pantazis D., Donnay J-P., 1996. La conception de SIG. Méthode et formalisme. Collection Géomatique. Paris, Hermès, 343 p.

Topping G., 1998. Introduction to the Special Issue of Marine Pollution Bulletin. Mar. Pollut. Bull., 35(1-6), (1-2).

Viescas J., 1997. Microsoft Access au quotidien. Microsoft Press, 969 p.

Chapitre 2

Technical aspects of data acquisition and display

Techniques d'acquisition et de représentation

Prevention or Cure? Electronic Navigational Charting around Australia

Ronald A. Furness

Australian Hydrographic Office, 8 Station Street, Wollongong 2500, Australia
rfurness@ozemail.com.au

Abstract

My thesis is quite straightforward! When it comes to pollution of the coastal zones, prevention is better than cure! The results of the infamous grounding of the *Exxon Valdez* reveal that we are all losers as a result of such catastrophes. The benefits of electronic charting are presented as a technological capability aimed at providing the mariner with greater safety margins. Some of the cartographic challenges presently being grappled with and met by the Australian Hydrographic Office's (AHO) cartographers are considered as they prepare the first authorized and thus, government backed, Electronic Navigational Chart (ENC) database of the inner shipping route through Australia's Great Barrier Reef. The preparation of electronic charts is a complex matter and time is needed before the world is adequately charted electronically.

Prince William Sound, 23 March 1989

With the benefit of the clarity that comes from hindsight, it is reliably understood that, had the *Exxon Valdez* been operating an Electronic Chart Display and Information System (ECDIS) containing Electronic Navigation Charts (ENC) then four alarms would have sounded before the ship slammed into Bligh Reef. As it was, the vessel strayed some one kilometre from the main shipping lane and hit the reef at speed. The resultant oil spill was the worst in American history but incredibly, in the scheme of things, was around the average for the more notorious oil spills. Some 42 million litres of oil spilling into the pristine waters of Prince William Sound might well have been the most costly environmental mistake of any American company but in world terms it was pretty ordinary! In fact, the *Exxon Valdez* barely made the top ten of such catastrophes!

Prince William Sound is on its way to environmental recovery, but it has a long way to go. It is reported that "several populations of sea fauna, including sea otters and the commercially valuable pacific herring on which other commercial fish species feed, are still struggling" (Fries, 1999). The town of Valdez, it seems, has learned that its very thorough preparations to combat the effects of an oil spill were inadequate and valuable lessons have been learned.

Clearly it would have been better for all concerned as well as the environment if the *Exxon Valdez* had not hit Bligh Reef. ECDIS with appropriate ENC content offers to reduce the incidence of such accidents and therefore, in my view, it is patently obvious that prevention is better than cure! Given that Australia boasts some of the most environmentally sensitive regions in the world, her maritime agencies have a vital interest in prevention. A key part of the strategy is the achievement of efficacious ENCs for use in ECDIS.

Background

The last decade or so has been a thrilling period in the development of nautical charting around the globe. This truly international activity has seen the development of ENCs to a point where they will soon, routinely, deliver a range of capabilities suited for use on a variety of ingenious programmed devices and applications. ENCs promise both improvements in productivity and increased safety margins to the navigation task of vessels at sea. However, progress has not been without its challenges! Government agencies and private commercial concerns around the world have co-operated, competed, fought, argued, created and generally excelled to bring electronic charting to fruition.

The decade's activity has resulted in international standards for electronic charting which promise to deliver to mariners authorized electronic charts of the highest standard. ECDIS is governed by four major standards. These are managed by the International Hydrographic Organization (IHO) and the International Maritime Organization (IMO) through a number of technical committees and working groups and the International Electrotechnical Commission (IEC). (IMO, 1995; IHOa, 1996; IHOb, 1996; IEC, 1998). The ECDIS Performance Standard (IMO, 1995) is the over-arching standard that provides the basic performance framework for ECDIS. It describes what functions and capabilities are required from ECDIS. It is complemented by the other standards. For a detailed description of ECDIS and its potential and limitations, see the reference at Ward *et al.*, (1999).

ECDIS is supported by the delivery to the market of complementary computer systems which potentially provide dynamic and real-time navigational capability to the ship's master, navigator, regulator, safety authority and ship's owners and crews simultaneously. Many commercial companies have pushed ahead to market, often brilliantly designed, navigational applications for viewing and integrating electronic charts with onboard ship sensors, such as the Global Positioning System (GPS). The result is that the market now offers many such products of various detail, quality, capability and theme.

Realisation of the potential increases in safety margins demands the highest quality and integrity of data in the electronic digital chart, the ENC. Compilation of electronic charts must ultimately rest on a full cartographic assessment of the best fundamental data available. The simple transference of existing, single product focussed cartography into the object oriented data models which underpin electronic navigational charts is inadequate, notwithstanding the fact that the exigencies of business dictate "acceptable" short-term alternatives, such as scanned or automatically vectorised paper charts. The whole ENC production process is presently testing the professional skills of cartographers around the world and in the Australian Hydrographic Office as the Office orients its future chart production capability towards the delivery of ENCs to the mariner.

The Australian Context

Australia is a relatively remote continent, almost the size of the United States and with a continental shelf of similar area. It has a population of approximately 18 millions. In order for Australia to meet its international charting obligations it needs to be clever and to exploit technology to the hilt. Those technologies about to be delivered to its new state-of-the-art, purpose built, hydrographic survey ships and already available from its Laser Airborne Depth Sounder have been world leaders, but still Australia struggles, like many other major hydrographic nations, to meet its obligations to modernise its nautical charts and deliver ENC (Nairn, 1994). Much of Australia's maritime area is not adequately surveyed to modern standards and the Australian marine cartographer will be forced for some time yet to meld together disparate data sets. This will impact on methodologies for the immediate future. It is clearly destined to be some time before Australia will have a complete ENC based totally on digital data that provides full bottom coverage.

Charting in Australia

The Australian Hydrographic Office (AHO) has been a traditional charting agency until relatively recent times, delivering to mariners authorized paper nautical charts. In the mid-1980s, Australia embarked on a program of modernisation aimed at transitioning its chart production methodology from a single, product base (paper charts), towards becoming a modern, hydrographic information supplier. The earlier computer-aided techniques used in the AHO were limited and limiting in that they modestly sought to assist chart production by replicating paper chart production methodologies. The main limiting factor in the 1970s and 1980s was, of course, technology: graphics terminals, screens, plotters, digital data collection, positioning; nevertheless, most of the main ideas were taking shape at that time for developing ultimate ENCs.

The AHO converted all of its charts to a raster scanned medium and routinely delivers charts in this form to mariners within a product regime that has mastered the updating requirements of the charts. The Australian Seafarer® service was introduced in 1997 (Rowland & Furness, 1998). Seafarer® is a fully electronic chart service providing digital reproductions of the official Australian paper charts in a raster scanned format. It is suitable for use in a wide range of maritime applications, from fully integrated bridge systems to stand-alone PC based Electronic Charting Systems (ENC). An integral part of the product is an update service, which provides the latest new editions and Notices to Mariners updates on a CD that automatically updates the charts.

However, the market clearly wants ENCs in vector format for use in ECDIS systems. The main limiting factor on all hydrographic offices, but especially the AHO, is the lack of available digital data. The AHO has embarked on a major capital investment which will see its data in digital form but in the interim must seek to find ways of bringing nationally authorized ENCs to the market sooner. Since 1998 it has been clear that, for the foreseeable future, ECDIS systems will need to be multi-fuelled. The authorized national ENC is that chart which is specified to "fuel" the data requirements of ECDIS. An ECDIS capable of utilising, for example, authorized ENCs and authorized raster charts as well as other publications could be said to be "multi-fuelled".

Many countries and private companies, in an effort to deliver ENC products to mariners and having regards to the paucity of available digital data, have looked to digitize their charts in a way that vectorises them and which meet the format specifications of the International Hydrographic Organization for ENC (S-52, S-57). Such an approach is useful in the shorter term and has been adopted in Australia. Willis (1998) has pointed out that the reasons such data sets of and around major ports were produced in Australia include:

- ECDIS testing and demonstration purposes;
- development of standard operating procedures for digital data capture;
- proof of concept for conversions from Autochart digital files (Autochart is the original feature-based chart production system introduced by the Australian Hydrographic Office in the mid-1970s);
- proof of concept for conversions from S-57 to other formats such as the Digital Nautical Chart (electronic chart to military specification), raster and paper chart;
- support of requirements raised within the Department of Defence and by maritime and port authorities in Australia;
- training of cartographic staff on the newer generation digital chart production systems.

However, the full benefits from electronic charting can only be gained ultimately with full, *ab initio* recompilation from first principles, rather than *via* the simplistic digitisation of the paper chart product.

The Benefits of Electronic Charting

The main benefits of electronic charting can be listed as follows:

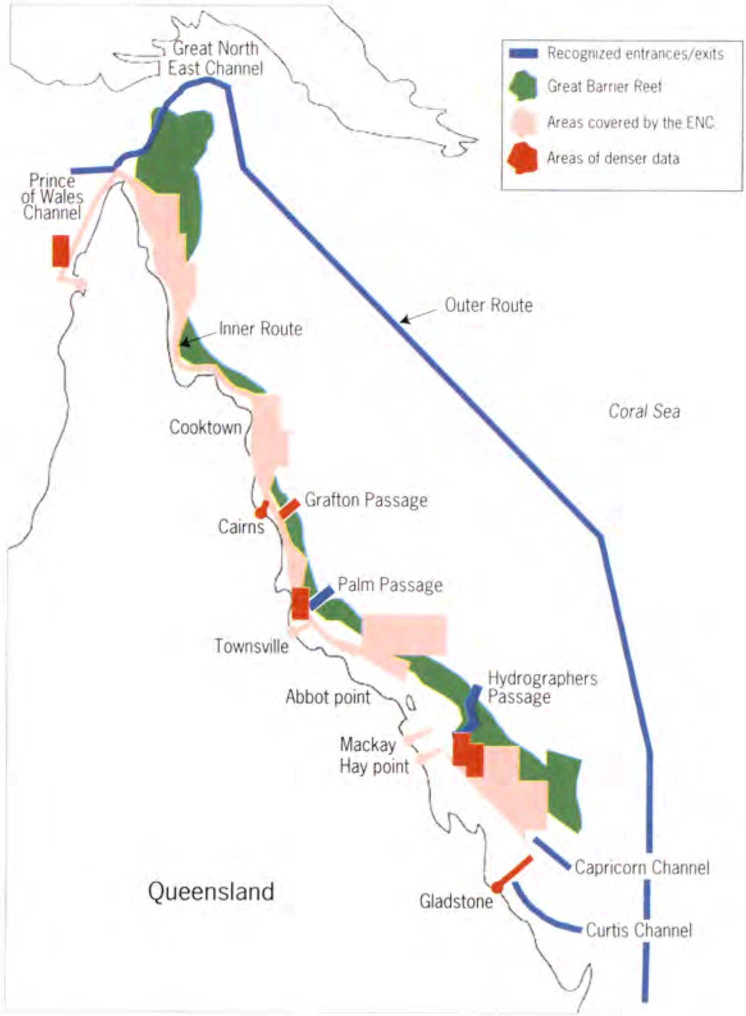
- provides instant, real-time, visual confirmation of the vessel's position against the graphic representation of the real-world;
- reduces stress and workload on the ship's bridge;
- minimizes the risk of grounding and consequent environmental disaster;

- chart updating is facilitated;
- data can be continuous and therefore there is no chance of "running out of chart";
- greater flexibility is afforded the master in blind pilotage situations;
- "black box" recording is facilitated;
- vessel traffic management and harbour control are facilitated;
- authorized electronic charts will eventually eliminate the need for the master to use paper charts;
- ships' owners can better schedule and redeploy their vessels for profit with less risk on the environment.

An Australian ENC in the Great Barrier Reef

Most readers will have heard of the Great Barrier Reef (GBR). Many people dream of visiting the GBR and they will necessarily do so by boat or ship. The GBR is the most navigationally complex region for Australia. The beauty of the Reef is its potential downfall since, although it is hazardous to shipping, shipping is more hazardous to it! The main navigational passage through the GBR is known as the Inner Route. Figure 1 illustrates the location of this route with some of the main routes through the Reef to the outer routes and deeper water. The Reef is a magnet for researchers and tourists. Being so environmentally sensitive it attracts world attention and is managed appropriately. The International Maritime Organization has declared the entire GBR a Particularly Sensitive Area. The GBR receives special attention from the AHO. Compulsory pilotage was introduced in October 1991 for ships transiting the GBR Inner Route and Hydrographers Passage and applies to all vessels of 70 metres or more in length as well as all loaded oil tankers, chemical tankers and gas carriers of any length.
Willis (1998) has stated that in response to international calls for hydrographic offices to expedite the release of official ENC data sets compliant with S-57 edition 3.0, and national calls to improve the state of electronic charting in the Inner Route of the Great Barrier Reef, the AHO undertook to produce ENCs of the Torres Strait and Inner Route. The first cells from Weipa in the Gulf of Carpentaria to the western approaches to Torres Strait have been trialled on the vessel, the *River Boyne*. Production effort progresses cells through Torres Strait and down to the Queensland port of Gladstone. This undertaking has imposed a number of significant challenges and questions that needed robust responses (Willis, 1998):
- there was a need to develop a comprehensive data capture specification for the ENC;
- was vectorisation of the existing paper chart the best way to present an ENC?
- could Australia create an ENC of a long narrow strip of waterway, such as one might capture a river, without converting all the paper charts covering that strip? The Inner Route of the GBR is about 1 000 km long by an average 10-20 km wide;

Figure 1
Schematic of Great Barrier Reef ENC.



- what compromise could be made in limiting the content outside the Inner Route?
- should more information be included within the Inner Route from source data?

The specifications adopted by Australia within the IHO guidelines for the Inner Route ENC are:
- depth contours at 1 metre intervals in critical areas derived from original source data;
- soundings initially only in critical areas;
- smaller scale charts to provide a backdrop;
- high resolution in critical areas;
- coverage of the Inner Route strip;
- adherence to IHO Specifications and Standard Display requirements.

Experiences from ENC production

Hydrographic offices, including the AHO in particular, have been aware for some time of the need for them to position themselves to be able to generate ENC, raster and paper charts products from the single moderated source data set. They are painfully aware that the data set must be maintained, as must be the products.

So marine cartographers producing ENCs must focus on new ways to present chart information. Paper products have tolerated regional differences in presentation. The dream of a single worldwide ENC coverage and the rigid demands of computer systems required to run these ENC databases means that myriads of minor differences are intolerable. No longer is the chart compiler able to have some determining role as to how some "feature" might be depicted, or even how far it might be displaced in position for aesthetic cartographic presentation, but she must be faithful to the "object", describing it and its relationships precisely. Thus, we are starting to see a shift in cartographic thinking here from the subjective to the objective. Subjectively defined graphic presentation is giving way to precisely defined and comprehensively described real-world object. Presently it remains a matter of degree.

There needs to be realised a changing view of data and the synergy that modern computers unleash for others such as environmentalists, researchers, legislatures, law enforcers, searchers and rescuers, coastal zone managers and so on. This list is by no means exhaustive but illustrates a largely untapped demand for hydrographers' data. It also serves to make the point that the marine cartographers' responsibilities are shifting away from "just" the mariner. As expert interpreters of the hydrographic and navigational data, cartographers are inexorably repositioning themselves and their professional role and obligation to society. If this is interpreted as drawing a long bow then consider the scramble for interpretive advice arising from the requirement for nations to define their various offshore zones!

Any cartographer who has worked for a major map or chart-producing agency will be aware of the push for minimising effort for derived mapping. The push continues and is almost achieved, conceptually, in the object oriented marine world. However, the mind processes of the cartographer as he defines objects are simultaneously spanning all possible uses of that object for a myriad of possible uses. So the mind is moving here from the particular (this scale, this use, this presentation) to the general (all possible scales, all possible uses, all possible presentations). The mariner, at sea, on a cramped bridge, with terrible visibility, with immense responsibility, unstoppable momentum and almost certain dependency on electronics, is interested ultimately in a fundamental binary equation - go or no go! The mariner is now able to relate precisely and absolutely to the real world in real time. A realisation of this must be uppermost in the mind of the cartographer interpreting the data in the comfort of an office, particularly when making "decrees" as to issues such as usage, quality, relative accuracy.

This is quite a shift in thinking for most chart makers and requires that they thus develop new paradigms.

The mariner is never able, as we were once entreated by Cervantes' *Don Quixote*, to "journey all over the universe in a map, without the expense and fatigue of travelling, without suffering the inconveniences of heat, cold, hunger and thirst". Chart makers need to come out from the comfort of their offices and start to experience some of the "heat, cold, hunger and thirst" of the real world as they make their charts.

An interesting issue for the cartographers engaged in ENC production is the increasing use of databased information such as lights, buoys, boundaries, text, photographs, attribute management, tomes and on. The actual compilation process is requiring compilers to focus more on the actual bathymetry and the construction of bathymetric polygons. When the aim is to include isobaths at metre or sub-metre interval, then the subsequent polygonisation is, to say the least, challenging. Overkill? Hardly, when increasingly mariners are demanding greater and greater detail and accuracy in order to rationalise their loads to minimum underkeel clearances in critically sensitive areas such as the GBR. The challenges for quality assurance and control are immense and are being faced as opportunities each day!

The present IHO specifications have been designed to a large extent from a cartographic perspective. To that extent they are limiting. However, future (decade plus?) improvements will ultimately see precise interaction between dynamic data (ship's draught, tidal models, ice edges, weather, for example) and the databased chart information and tolerances between the go/no go margin will shrink. Thus cartographers need to be far reaching in their present day mind sets as they focus on production issues.

A dilemma between the need for certainty in our specifications and processes and the need for innovation and flexibility is continuously present. Notions of "multi-fuelling" with various data sources, in itself a rational and transitional option, forces compromise and stifles creativity and innovation.

When marine cartographers deliver a paper chart the medium is very much the message. Rigid and generalised in presentation, the presentation could be said to conform to the principle that "one size fits all"! The advent of digital data separates the medium from the message in that the message to the mariner must come *via* an electronic chart system, or ECDIS. This has spawned a number of Faustian relationships between HOs and manufacturers with few clear lines of demarcation in respective roles. This is clearly part of the development conundrum, but as progress is made there are signs that the market place is better realising proper roles for authorized government agencies and the commercial imperatives of system manufacture.

The Impact of Electronic Charting on the Mariner

However fast the navigator might be capable of plotting his course the fact is that by the time he has achieved it, the vessel is actually somewhere else.

The overwhelming benefit of an electronic navigation chart is that it can actually vary the display to suit the requirements of the actual voyage. It can sense the computed depth against actual depth under the vessel's keel and, based on the draft of the vessel at the time, can alert the mariner to his situation, not only positionally, but in actual relationship with the bottom of the vessel.

When the advantages of digital radar are added, then it is easy to represent other traffic in a region relative to the actual position of the vessel.

Alarms sound (as they would have had such equipment been available on the *Exxon Valdez*) if a "wheel over" is missed, if the vessel strays too far from the planned path, if the vessel's path is projected into too shallow water and if the vessel approaches too close for safety to the land or a navigation aid. However clear this is though, since the image is of a rasterised paper chart, "what you see is what you get". Since the mariner ultimately requires to make a "go or no go" decision we see that vectorised data is "better" since data extraneous to the operation of the vessel can be eliminated by switching it off. An example would be all soundings and all imagery greater than 10 m deeper than the ship's draft.

We are starting to see emerging hybrid charts for ECDIS which provide a combination of vector and graphic imagery.

Examine the image in figure 2. It represents a section of the Endeavour Strait, which is within the Torres Strait and which is within the Great Barrier Reef charting project detailed above.

Figure 3 illustrates the same area with ENC cells taking priority where they have been finalised. Immediately, one can see the clarity of the presentation but before one gets the idea that such apparently simplistic presentations of the chart information, one should examine figure 4 which presents the same area with all available underpinning information displayed.

The strength of the ECDIS capability can be seen in these simplified diagrams. The mariner's decision-making is underpinned by a simplified graphic which itself is underpinned by a strong database which is capable of being interrogated intelligently by the mariner in a way directly relevant to the particular circumstances of a particular voyage. Margins of error are thus reduced and safety is enhanced.

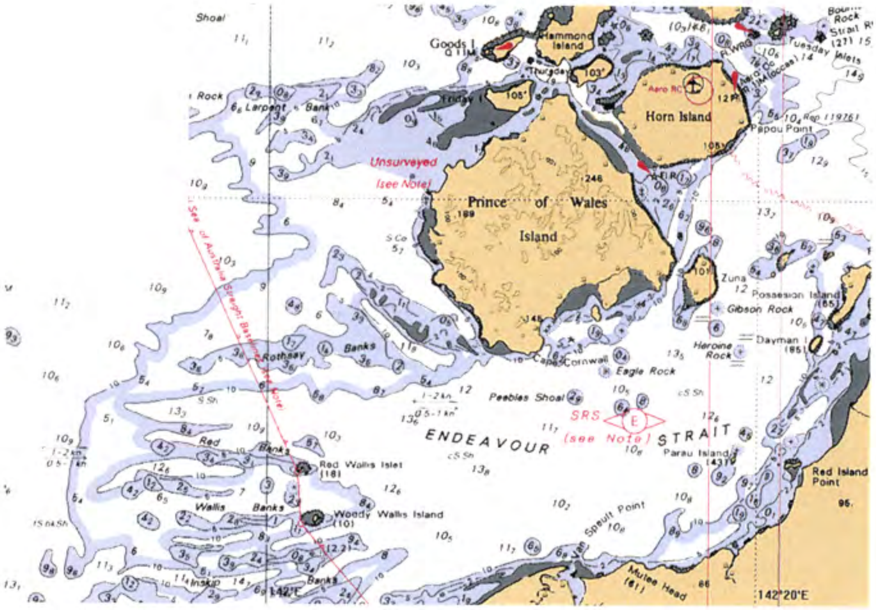


Figure 2 - Rasterised chart image in Torres Strait.

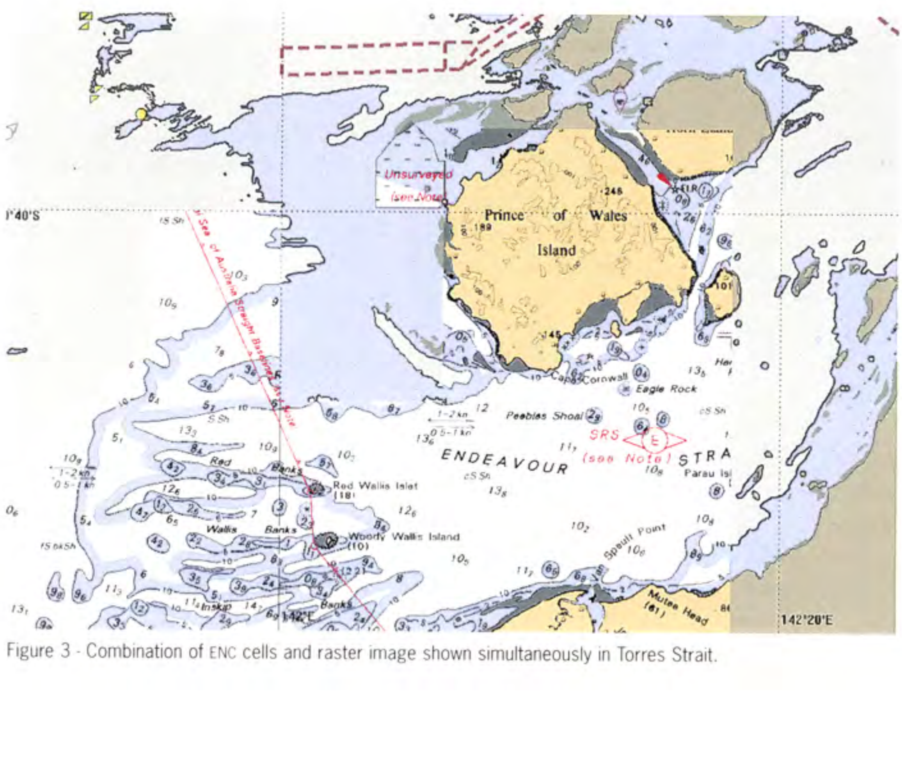


Figure 3 - Combination of ENC cells and raster image shown simultaneously in Torres Strait.

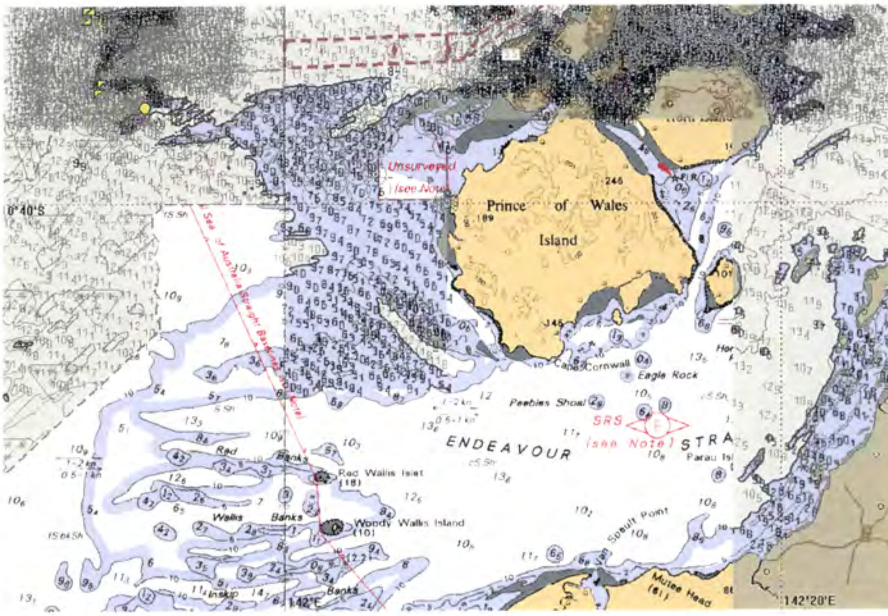


Figure 4 - Torres Strait area showing full underlying dataset where ENC cells exist.

Conclusions

The promised benefits to the environment from safer navigation provided by authorized ENCs within an approved ECDIS system are overwhelming. We are potentially all winners! So is the environment! The cartographic paradigm for marine cartography is shifting from a more subjective and perhaps narrower professional role to one that is more general, or wider, and more objective in its professionalism. ENC compilers will be required to be more eclectic in their thinking and will be able to project forward as they work to the multiple uses their work will be put. They need to be acutely aware of the needs of the mariner. As one wit has said, "we are at the bleeding edge"! If that is the case then the experiences are presently being written in blood, but finally, they are being written and we are rising to meet the challenges! The environment and the safety of vessels and their crews should all benefit as should the ship owners. Potentially a "win-win" for all concerned, arising out of the imperative for electronic charts which in turn leads to better charts.

Bibliographic references

Fries P, 1999. Ripple effect: 10 years after the *Exxon Valdez*. Aust. Financial Rev. Mag., April.

International Electrotechnical Commission (IEC), 1998. Maritime navigation and radio communication equipment systems - Electronic chart display and information system (ECDIS) - operational and performance requirements, methods of testing and required test results, IEC 61174.

International Hydrographic Organization (IHOa), 1996. Transfer Standard for Digital Hydrographic Data, Publication S-57, Edition 3.0, November.

International Hydrographic Organization (IHOb), 1996. Specifications for Chart Content and Display Aspects of ECDIS, Special Publication, 52, 5th ed., December.

International Maritime Organization (IMO), 1995. Performance Standards for Electronic Chart Display and Information Systems (ECDIS). IMO Resolution A 817(19).

Nairn R., 1994. Royal Australian Navy laser airborne depth sounder: The first year of operations. Int. Hydrogr. Rev., Monaco, LXXI(1), March.

Rowland B.T.J., Furness R.A., 1998. Australian digital navigation charts, proceedings: Adding a spatial dimension to business. National conference of the Mapping Sciences Institute. Australia, Fremantle.

Ward R.E., Roberts C.S., Furness R.A., ECDIS, 1999. State of the art in nautical charting in marine and coastal geographic information systems. Wright D., Bartlett D., Taylor & Francis (eds).

Willis R.J., 1998. Towards AUS ENC ONE, proceedings, Institution of Surveyors. 39th Australian Surveyors Congress, Launceston.

Airborne Laser scanning: an operational remote sensing technique for digital elevation mapping in coastal areas

Emmanuelle van de Kraats

Geodan Geodesie bv, Koningslaan 35, 1075 AB Amsterdam, The Netherlands
info.geodesie@geodan.nl

Abstract

Integrated Coastal Zone Management (ICZM) is a vital task for the Netherlands. Therefore the availability of up to date topographic and thematic information is of significant importance. For this reason, much attention has been given to find a way of elevation data acquisition, which is accurate, has a high point density and is time and cost efficient. Taking into account the mixture of criteria, airborne laser scanning has been very soon sensed as an appropriate tool for Digital Terrain Model (DTM) generation. The laser scan technique has evolved in a few years from an experimental stage to wide use in operational projects. The first operational project was undertaken in 1994, by the Dutch company Geodan Geodesie. This project consisted in providing DTMs, which were integrated into a GIS and used to model morphological changes of dune areas. Since this time, airborne laser scanning has been currently used to perform the yearly survey of the entire Dutch coast. This article will first explain the principle of the airborne laser scan technique. In a second part, based on two projects undertaken by Geodan Geodesie, applications of laser scan technique for ICZM will be presented.

Résumé

La gestion intégrée du littoral est une tâche vitale aux Pays-Bas et la disponibilité de données topographiques et thématiques récentes est d'une importance primordiale. Pour cette raison, beaucoup d'efforts ont été développés pour trouver une technique d'acquisition de données d'élévation précise, rapide, bon marché et offrant une forte densité de mesures. À cet égard, la scannographie aéroportée a été très vite pressentie comme un outil approprié pour la génération de modèle numérique de terrain (MNT). Elle est passée en quelques années du stade expérimental à une large utilisation. Le premier projet opérationnel a été réalisé en 1994 par l'entreprise néerlandaise Geodan Geodesie bv. Ce projet consistait à fournir un MNT destiné à être intégré à un SIG et utilisé pour modéliser les changements morphologiques des zones de dunes. Depuis, la scannographie aéroportée est utilisée pour le levé annuel de la totalité du littoral néerlandais.

Cet article explique d'abord le principe de la scannographie aéroportée puis, s'appuyant sur deux projets entrepris par Geodan Geodesie bv, une présentation est faite de son application à la gestion intégrée du littoral.

Introduction

Laser scanning is a new technique, which enables Digital Elevation Model and Digital Terrain Model generation. It has very specific characteristics like the ability to generate DTMs in forest areas. Other advantages, which have been seducing Dutch users are the quick data acquisition and processing, the high point density and the relative low cost of laser scan data. The need for elevation data in the Netherlands in the field of Coastal Zone Management (CZM) has stimulated the development of this new technique. Laser scanning is now an operational tool, widely used in data acquisition for CZM in the Netherlands. For four years now, the entire Dutch coast has been surveyed every year by means of laser scanning. Since 1994, Geodan Geodesie has been involved in data acquisition using the ALTM 1020 laser scanner for the management of the Dutch coastal zone.

Airborne laser scanning

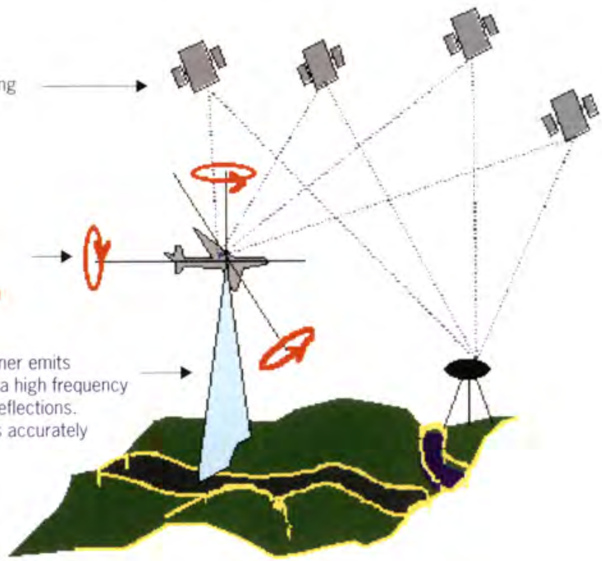
Concept

The principle of laser altimetry is rather simple. The basic idea is that knowing the X, Y, and Z co-ordinates of a laser placed in a plane, the attitude of the plane and the distance travelled by the laser beam, it is possible to determine the X, Y and Z co-ordinates of the points hit by the laser beam. This idea has first been applied to measure terrain profiles. The laser altimetry technique has been improved by sweeping the laser beam, with the help of a mirror, across the flight track. In this way a swath of the surface is surveyed. To implement this basic idea into an operational technique, several instruments and techniques are required. A GPS receiver placed in the plane and a GPS receiver placed on the ground permit to position the laser beam during the flight by means of kynematic differential Global Positioning System (dGPS). An Inertial Navigation System is used to determine the changes in attitude of the laser scanner due to plane movements. The laser scanner is used to perform distance measurements and the mirror of the laser scanner gives the orientation of the laser pulses (fig. 1). The laser pulses are emitted with a high frequency providing up to several elevation measurements per square metre depending on the laser scanner parameters and flight characteristics.

Laser scanner characteristics

The laser scanner used in the under-mentioned projects (ALTM 1020) emits laser pulses with a wavelength of 1 047 nm at a maximum pulse

Figure 1
Laser scanning concept.



frequency of 5 000 Hz. With a divergence angle of 0.25 mrad, the resulting foot print size of the laser beam is 22.5 cm when flying at 900 metres.

The mirror reflecting the laser beam along a scanned line has a maximum scan angle of 20° on both sides of the laser scanner nadir, resulting in a 700 metre wide scan swath when flying at 1 000 metres. The mirror scan frequency is up to 20 Hz. The ALTM 1020 can scan large areas with a point density of one point per 25 m^2, up to several points per square metre. As explained by Kost *et al.* (1997), changing the laser pulse frequency allows for a variation in density of reflection points within a scan line and the distribution of measurements over an entire project area can be controlled by flying height, ground speed, scan angle and scan rate. Therefore, laser scanner parameters and flight characteristics are chosen in order to achieve the point density specified by the client. The high point density makes laser scanning an interesting technique for digital elevation and digital terrain modelling.

Digital Elevation Models and Digital Terrain Models

When a laser scanner emits a pulse, it can be partly reflected by a branch or the top of a tree, and the other part of the pulse can continue its way until it reaches the ground. In that case, the first reflected pulse refers to the branch or the tree-top while the last one refers to the ground. When recording the first reflected pulse, laser scanning can be used to get elevation values of objects standing on the terrain like power lines or tree canopy. In setting the laser pulse detector to record only the last received pulse, the proportion of measurements referring to the ground will increase. In performing the survey when trees are without leafs, the proportion of ground points hit by the laser beam will be optimal, facilitating the DTM generation even in forested areas. This particular property of providing ground level points also in vegetation covered areas has been one of the first aims and applications of laser scanning, as there is no alternative technology available (Ackermann, 1997). DTMs generated by means of laser scanning can achieve an accuracy of 15 cm in X and Y and 10 cm in Z. As underlined by Lemmens (1997), laser scanning technology has proven to be superior to other 3D capturing methods, such as photogrammetry, tachymetry and terrestrial GPS, concerning accuracy, point-density, time efficiency and cost criteria.

Laser scanning applied to Coastal Zone Management

Coastal zones in the Netherlands provide many functions for humans and for nature. The availability or storage of fresh water is essential for coastal ecosystems as well as for agriculture and drinking water supply. Dune formation secures a reliable natural defence against the influence of the sea. Interactions between land and water enable coasts to provide excellent opportunities for economic development. Laser scanning has been in an early age sensed as a useful tool for terrain elevation data acquisition and for this reason much attention has been given to develop this new technique into an operational tool.

The following will give two examples of operational laser scanning projects applied to coastal zone management.

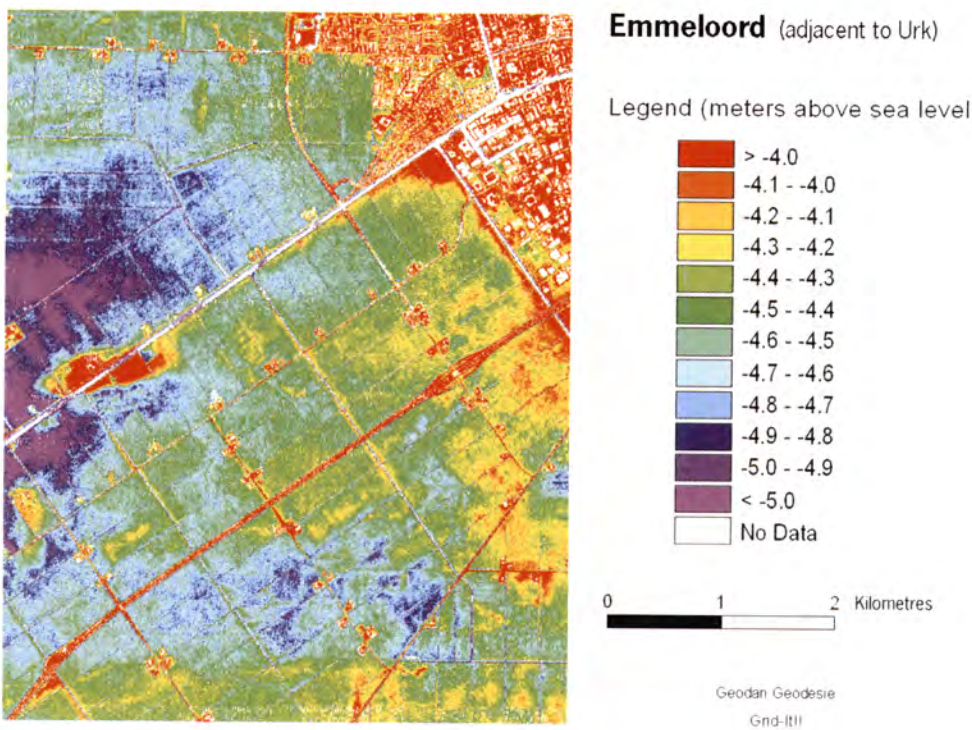


Figure 2
Example of DEM generated from laser scan data in the neighbourhood of Emmeloord situated in the center of the Netherlands.

Projects goals

The first example is an operational project of data acquisition, which took place in 1994 on the demand of waterworks companies. The water company of the city of Amsterdam (Gemeentewaterleidingen Amsterdam, GWA) and the waterworks service of the region North Holland (Waterleidingbedrijf Noord-Holland, PWN) chose the laser scan technique to acquire a DTM of their control areas. The surveyed areas were situated along the North Sea coast covering an area of 40 km by four kilometres. The GWA and the PWN needed a DTM of their control areas for many uses. A first example was the use of the DTMs for re-structuring projects, to determine ground resistance. A second example was the production of maps with an accurate rendering of the relief for orientation in the field. DTMs were also needed to integrate elevation data in a hydraulic model of the dune area to permit the study of the effect of water extraction from the dunes on the flora and fauna in the frame of hydro-ecological research. In this study, the water height under ground level plays an important role. The combination of ground level with a vegetation map and the depth of the ground water by means of water company's GIS provided an accurate image of the possible development of the natural dune vegetation, while it permitted hydrologists a better evaporation determination. Water works companies also wanted to use the DTMs as basic information for relief dune spontaneous changes monitoring and for geomorphology studies of the dune vales and dune ridges (Han, 1995).

The second example is an operational project, which took place in 1996, 1998 and 1999 to acquire elevation data for the Survey Department. The Survey Department, which is part of the Directorate General of Public Works and Water Management is responsible to provide geo-information for coastal defence, infrastructure and river management in the Netherlands. For this reason the Survey Department has been undertaking yearly measurements of the Dutch coast to monitor the structural regression of the coastline in order to take active measures to preserve the coastline and for purpose of coastal defence. As explained by Huising & Vaessen (1997b), these yearly measurements used to be performed by means of photogrammetry in measuring profiles every 200 m along the coast, permitting to establish the position of the coastline. The photogrammetric process was time consuming and expensive. For this reason the Survey Department sought for an alternative technique for elevation determination. This research led the Survey Department to opt in 1995 for the laser scan technique to perform their yearly survey of the Dutch sedimentary coast, providing data for coastal defence purposes and coastal erosion assessment. With a new DTM every year, the Survey Department is able to model the yearly variations of coast morphology due to wind and sea action.

Density of the scanned points

The density of the scanned points is an important characteristic of a DTM generated from laser scanning. The clients specify the required point density based on the use of the elevation information. The laser scanner parameters and the flying characteristics are determined in function of the required point density. For the 1994 project, the average point density asked by the GWA was 1 point per 12 m^2 (3.5 m * 3.5 m) while the PWN required 1 point per 4 m^2 (2 m * 2 m) (Han, 1995). For the 1996 survey of the Dutch coast, the Survey Department asked for a point density of 1 point per 16 square metres. After analysis of the processed data, it came out that the point density was inappropriate to dune areas. Dune tops were removed and valley bottoms were flattened. The spatial resolution was too low to model the terrain elevation variations. To overcome this problem, the Survey Department decided to increase the point density to 1 point per 6 m^2, in order to get proper coastal zone modelling.

Data processing

Data processing, which is widely automatic, consists in determining the co-ordinates of the scanned points and classifying the points as being ground points or else.

A first step in data processing consists to determine the position of the plane during the survey using the dGPS measurements. The high reliability of the plane position determination is due to the use of several multiple GPS base stations in the field during the survey (Looman, 1997). Once the plane position along the flightline is determined, the position of the laser scanner is interpolated along this flight line considering the attitude changes of the laser scanner during the flight. Then X, Y, Z, co-ordinates of the scanned points can be computed using the position of the laser scanner, the direction of the laser beam and the distance between the laser scanner and the scanned points. The resulting point co-ordinates set includes data points resulting from objects like houses and from vegetation in dense vegetation areas (Looman, 1997). Making use of the spatial relation between neighbouring points, they are classified either as ground points or as object/vegetation points.

Once the co-ordinates of the scanned points are generated and classified, the next step consists in performing quality controls and applying corrections.

Quality control and achieved results

The quality controls of the DTM are performed in two ways. First an internal quality control is performed in analysing elevation differences in overlapping areas of adjacent strips and using a transversal control strip. This overlaps analysis consists in making sure that elevation differences in the ground data do correspond to topographical variations of the terrain and are not due to roll or shift in the data. Possible roll or shift in the strips are then detected and corrected. Once the elevation variations describe the terrain elevation variations, external controls are performed to check the relative position of the obtained model with the terrain level. To do so, ground points giving Z control values are used.

For the quality control of the 1999 project, some ground measurements have been performed on flat areas to provide reference Z values. One of these control areas is situated on Terschelling island (one of the seven islands of the north Dutch coast). This control area is a grass field of 2,70 km^2, where 209 reference points have been determined. There were 7 806 laser scanning measurements corresponding to this area. The average height difference between the reference points and the laser scanning measurements for this control area was - 5 cm and the standard deviation was seven centimetres. The quality of the data depends on the ground vegetation coverage. The water work companies and the Survey Department projects required a standard deviation of maximum 15 cm on the Z component. This accuracy has been achieved for both projects. Although planimetric accuracy can be assessed in using houses or linear man made objects, for the coastal zone management projects described, the quality criteria of the data was specified by means of systematic error and standard deviation on the Z component only.

Figure 3c shows some examples of yearly changes in coastal areas due to wind and sea action, calculated from the 1998 and 1999 dataset of Texel island (another of the seven islands).

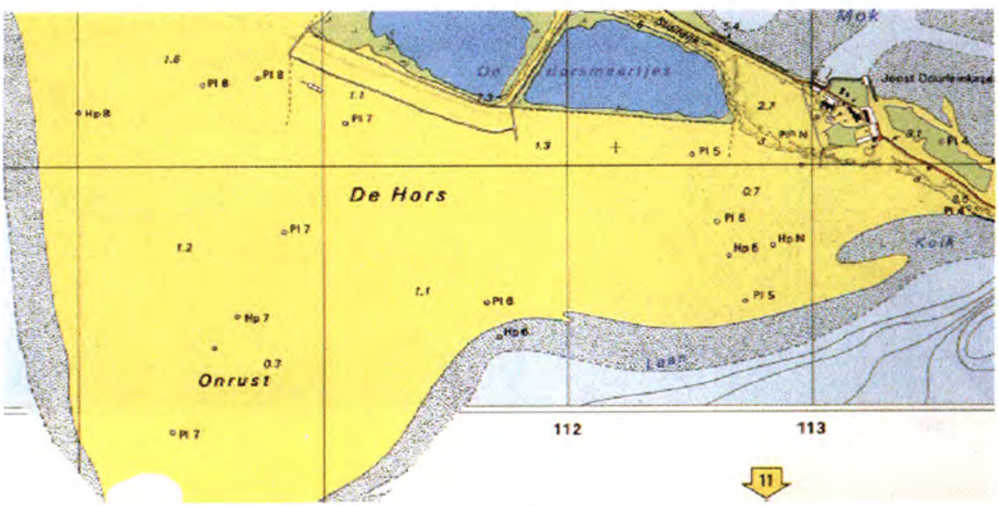


Figure 3a - Map of the sandy coast area in the South of the Texel island (scanned from Wolters & Noordhoff, 1996).

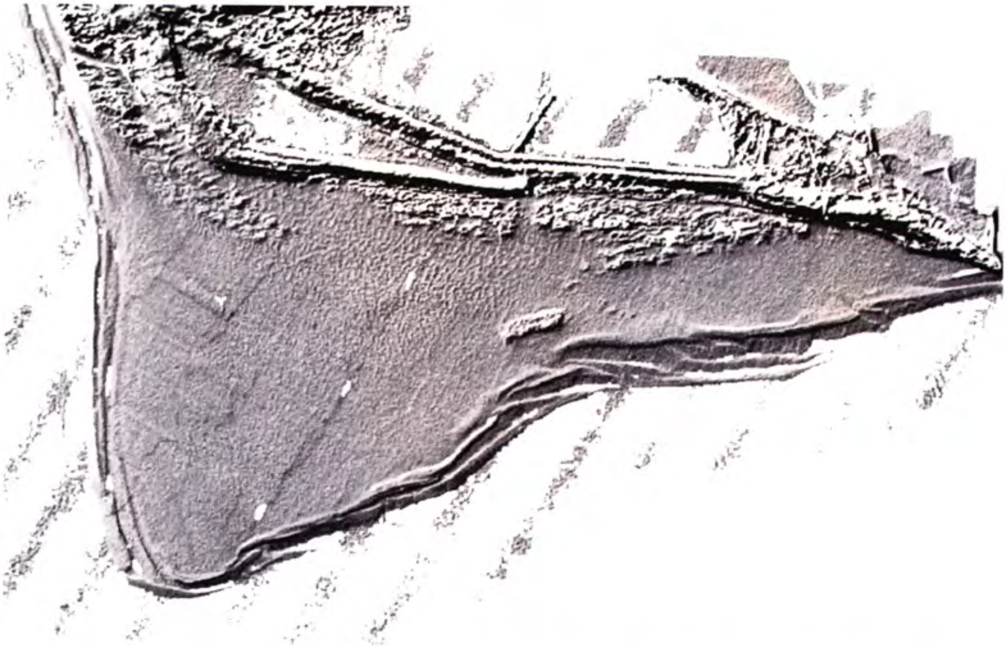


Figure 3b - Hill-shade representing the Digital Terrain Model of the south part of the Texel island generated from the 1999 dataset.

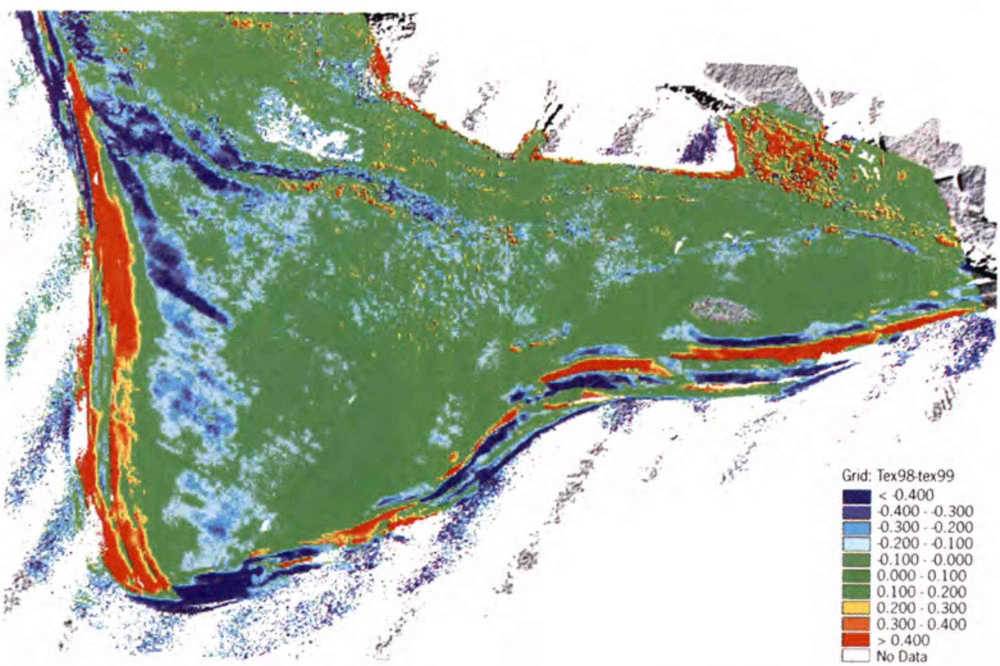


Figure 3c - Difference between the DTM of the Texel island generated from the 1998 dataset and the DTM of the same area generated from the 1999 dataset. Elevation differences are due to morphological changes due to wind and sea actions on the coastal zone. Elevation differences are expressed in metres.

Conclusion

Dunes, beaches and inter-tidal zones are particularly difficult to survey and therefore elevation data are difficult to acquire. Since laser scanning has reached an operational level, this new remote sensing technique has been able to provide an alternative to elevation acquisition of coastal zones areas. Laser scan technique is characterized by a high density and high accuracy of elevation information. As it is an airborne technique, data can be quickly acquired and few ground measurements are needed. Because of these characteristics, laser scanning is particularly adapted to generate DTMs of coastal zone areas.

Using a new technique is always a challenge. In the first undertaken projects as those presented in this article, it has not been easy to specify the suitable point density neither formulate conditions under which the survey should be performed in order to reach the aimed accuracy. These last six years of experience have helped to clarify these issues. The undertaken projects has enabled to determine the suitable number of reference areas, the maximum distance between the ground GPS station and the plane as well as the most suitable number of transversal strips. Large efforts have been invested in order to develop suitable software to process the data and define methods and tools to control the quality of the DTMs generated. In six years time the hardware specifications have increased enabling to acquire higher scanned point density and to minimise flying time. Constant progresses are being done and the reliability of the laser scan technique is growing. The results obtained in the field of coastal zone management has led the Survey Department to use laser scan technique to generate a DEM of the whole Netherlands with a point density between one per 16 m^2 to one per square metre in certain areas (Huising & Vaessen, 1997a). This last project shows the importance that laser scanning is getting in elevation data acquisition in the Netherlands.

Bibliographic references

Ackermann F., 1997. Airborne laser scanning - A brief status review. Barichenko S. & Reuter R. (eds), 3rd EARSeL workshop on lidar remote sensing of land and sea, Estonia, 85-88.

Flood M., Gutelius B., 1997. Commercial implications of topographic terrain mapping using scanning airborne laser radar. Photogr. Eng. Remote Sensing, 63(14), 327-329, 363-366.

Han C.S., 1995. Vliegtuig-laserscanning een onderzoek naar de toepasbaarheid van een moderne remote sensing inwinningstechniek vooe het meten van digitale terreinmodellen in NGT. Geodesia, 2, 89-93.

Huising J., Vaessen E., 1997 (a). Evaluating laser scanning and other techniques to obtain elevation data on the coastal zone. ERIM (ed.). *In:* Proc. 4th Int. Conf. on remote sensing for marine and coastal environments, Orlando, Florida, part. II, 510-517.

Huising J., Vaessen E., 1997 (b). Laser scanning. Eur. Assoc. Remote Sensing Lab. Newslett., 32, 5-8.

Kost W., Loddenkemper M., Petring J., 1997. 3rd EARSeL workshop on lidar remote sensing of land and sea. Barichenko S. & Reuter R. (eds), Estonia, 89-96.

Lemmens M.J.P.M., 1997. Accurate height information from airborne laser-altimetry. *In*: IGARSS'97, Int. Geosci. Remote Sensing Symp., Singapore, 222-224.

Looman P., 1997. Airborne laser scanning by Geodan Geodesie. Eur. Assoc. Remote Sensing Lab. Newslett., 32, 12-15.

Wolters & Noordhoff (eds), 1996. Grote povincie Atlas 1:25 000 Noord Holland, 8 p.

Alarme de précision pour les lignes de côte des ECDIS

Thomas Devogele[1], Yann Riffault[2]

(1) École Navale, laboratoire SIGMa, Lanvéoc Poulmic, BP 600, 29240 Brest Naval, France
devogele@ecole-navale.fr

(2) Institut d'ingénierie informatique, 3IL, 43 rue Sainte-Anne, BP 834, 87015 Limoges Cedex, France

Résumé

L'ECDIS procure des avantages indéniables en ce qui concerne la navigation dans les eaux restreintes. L'utilisateur a souvent une sensation de sécurité absolue. Or, sa sécurité dépend entre autres de la qualité des données employées (position du navire et précision des objets de la carte électronique). Hélas, le contrôle de la position des objets de la carte numérique est rarement abordé. Cet article propose une alarme de précision pour les lignes de côte. L'alarme est basée sur le calcul de la corrélation entre la ligne de côte de la carte numérique et celle du radar. Elle utilise la vectorisation de la ligne radar et le calcul de la distance linéaire de Fréchet entre ces deux lignes. Elle sera déclenchée si la distance est supérieure à la précision nécessaire à la sûreté du navire. Cette fonction peut rendre les systèmes de navigation plus fiables en fournissant un contrôle embarqué de la précision géométrique de données fondamentales.

Abstract

ECDIS offers very real advantages for navigation in restricted waters. The user often has a feeling of absolute safety. However, this security also depends on data quality (vessel positioning and precision of electronic chart objects). Unfortunately, checking chart objects is rarely considered. The aim of this article is to define a precision alarm for ECDIS shoreline, based on the correlation computation between electronic chart and radar shorelines. This alarm uses the vectorization of the radar shoreline and the computation of the Fréchet distance between these two lines. It will be triggered if the distance is superior to the precision necessary for safe navigation. This process improves safety at sea. It provides a embedded check on geometric precision for basic data.

Introduction

Les systèmes de cartographie électronique et plus particulièrement les ECDIS (Electronic Chart Display and Information System/Système d'information et de visualisation de cartes électroniques) procurent des avantages indéniables en ce qui concerne la navigation dans les eaux restreintes (Proteau, 1995). La visualisation du positionnement, le suivi de la route réelle par rapport à la route planifiée, et les diverses alarmes (IMO, 1996) font en sorte que le navigateur soit en contact direct avec toutes les données pertinentes pour la conduite du navire. L'utilisateur a ainsi une sensation de sécurité absolue. Or, sa sécurité dépend de la qualité des capteurs (radars...) et des moyens de positionnement (GPS, dGPS...). Elle résulte aussi de la précision, de l'actualité et de la complétude des données de la carte papier ou électronique. Actuellement, les limites du positionnement à l'aide d'un GPS ou d'autres systèmes sont maîtrisées (Botton, 1996). De même, les erreurs radar azimutales (erreur azimutale propre au radar et erreurs engendrées par le gyroscope) ou radiales sont connues. Par contre, la précision, l'actualité et la complétude des données de la carte électronique et leur contrôle sont rarement abordés. Or, en eaux restreintes, le contrôle de cette précision est essentiel afin d'éviter l'échouement. Il est fondamental dans les zones où les objets peuvent bouger (zones de bancs de sable, coralliennes ou de glace) ou avoir été cartographiés avec imprécision. Un nombre considérable de cartes électroniques vectorielles ou maillées, vendues par des fournisseurs privés, sont dérivées de cartes papier existantes qui ne sont pas suffisamment précises pour permettre la navigation en eaux resserrées. De plus, certaines de ces cartes sont fondées sur des levés très anciens, antérieurs à l'adoption de systèmes de référence géodésique et sont réalisées en fonction des pratiques traditionnelles de la navigation (sans dGPS). Ces anciennes cartes produites même après l'avènement des systèmes de positionnement électroniques n'ont pas l'exactitude régionale requise pour être utilisées par le DGPS. En général, les navigateurs disposent maintenant d'un positionnement plus exact avec le dGPS que les hydrographes il y a vingt ans (Goodyear & Rae, 1996).

Pour répondre à ce problème, la superposition de l'image radar sur l'ECDIS a souvent été proposée (Goodyear & Rae, 1996). De nombreux navires y ont recours afin d'améliorer la sécurité. Si la rétrodiffusion radar ne coïncide pas avec la ligne de côte indiquée sur la carte, il faut alors s'interroger sérieusement sur la précision de cette ligne ou supposer une défaillance du dGPS ou du radar. Cette technique a, par exemple, été utilisée par le navire garde-côte américain *Juniper* (Sletto, 1996) qui a pu comparer rapidement la position réelle de bouées avec leur position sur la carte numérique et constater leur dérive à cause des glaces.

Actuellement, ce contrôle est visuel. Cet article propose une alarme automatique de précision des lignes de côte pour les ECDIS, en eau restreinte. L'alarme est basée sur le calcul de la corrélation entre la ligne de côte de la carte et celle du radar. Elle utilise la vectorisation de la ligne radar et le calcul de la distance linéaire de Fréchet entre ces deux lignes. Elle sera déclenchée si la distance est supérieure à la précision nécessaire à la sûreté du navire. Ce processus permettra également de localiser et de visualiser les sections de la côte imprécises. Cette fonction a pour but de décharger l'opérateur du contrôle manuel et de détecter automatiquement les zones où le trait de côte de la carte ne correspond pas au trait de côte fourni par le radar. Avant de décrire les principes et le fonctionnement de l'alarme de précision, le but et les outils nécessaires au contrôle qualité des objets linéaires sont exposés ci-dessous.

Le contrôle qualité du linéaire

En terme de sécurité, le contrôle de la qualité d'éléments linéaires tels que les lignes de côte est fondamental. Il doit être réalisé tant par les producteurs que par les utilisateurs. Il repose essentiellement sur des techniques de mesure de la corrélation (mesures de distance, de ressemblance morphologique) entre la ligne à contrôler et une ligne de référence.

Le contrôle qualité

Le contrôle qualité regroupe l'ensemble des actions de mesure, d'une ou plusieurs caractéristiques d'un produit et de comparaisons aux exigences spécifiées (ISO, 1994). La norme S-57 (IHO, 1996) pour le transfert des cartes numériques marines prévoit que des méta-informations sur la qualité des données (source des données, précision, actualité) pourront être fournies avec les données. Ces méta-informations sont essentielles pour que les données soient affichées à des échelles compatibles avec leur précision.

Les fournisseurs de données se doivent de fournir à l'utilisateur des données répondant aux attentes des utilisateurs en termes de qualité. Pour cela, ils définissent un mécanisme d'assurance qualité (ISO, 1994). Ce mécanisme doit inclure un contrôle du jeu de données. Ce contrôle peut être réalisé soit par échantillonnage (des petites zones sont contrôlées par des jeux de données plus précis), soit par comparaison avec un autre jeu de données. Par exemple, les lignes de côte peuvent être contrôlées par corrélation avec les lignes de côte d'une carte numérique terrestre.

Malheureusement, les méta-informations sur la qualité des données sont encore souvent vagues, voire inexistantes. De plus, les données fournies ne répondent pas toujours à des normes de type S-57 (IHO, 1996) et peuvent être anciennes. Les utilisateurs ont donc besoin de contrôler les données en les comparant avec d'autres données, afin d'obtenir ces informations et de vérifier que les données soient à jour. Ce contrôle peut être embarqué. Dans ce cas, une alarme sera déclenchée si le contrôle s'avère négatif.

Ces comparaisons sont réalisées à l'aide d'un processus d'appariement encore appelé conflation. Ce processus consiste à établir les correspondances entre les objets géographiques issus de différentes sources qui représentent le même phénomène du monde réel. Il est réalisé en prenant en compte la forme des objets, leur position ainsi que leurs liens avec les objets les entourant. Il est utilisé dans de nombreuses applications (Devogele, 1997) manipulant l'information géographique : regroupement de bases de données juxtaposées, propagation des mises à jour dans une base de données clients, recalage de données sur un référentiel, intégration de bases de données géographiques (BDG), contrôle qualité, superposition de couches pour fusionner les géométries.

La distance linéaire de Fréchet

Pour comparer la géométrie de deux objets ponctuels, la distance euclidienne (d_E) s'impose. Par contre, pour comparer la géométrie de deux objets linéaires, plusieurs distances et plusieurs outils de comparaison de leur forme existent. En terme de précision de la position, les distances entre ces objets sont les mesures les plus pertinentes. Plusieurs distances peuvent être employées (Devogele, 1997). Certaines reflètent l'écart moyen entre les deux lignes (distance moyenne), d'autres représentent l'écart maximum entre les deux lignes (distance maximum).
La distance de Fréchet est une distance maximum entre deux lignes orientées. Elle s'appuie sur la propriété suivante : toute polyligne orientée est équivalente à une application continue f : [a, b]→V où a, b ∈ $\Re$, a<b et V est l'espace vectoriel. La distance de Fréchet (d_F) est la suivante :
soit f : [a, a'] → V et g : [b, b'] → V' deux polylignes et || || la norme usuelle,

$$d_F(f,g) = \inf_{\substack{\alpha:[0,1]\to[a,a'] \\ \beta:[0,1]\to[b,b']}} \max_{t\in[0,1]} \left\| f(\alpha(t)) - g(\beta(t)) \right\|$$

Une illustration intuitive de la distance de Fréchet est la suivante : un maître et son chien suivent deux chemins. Ils avancent ou s'arrêtent à volonté, indépendamment l'un de l'autre, mais ils ne peuvent pas revenir sur leurs pas. La distance de Fréchet entre ces deux chemins est la longueur minimale de la laisse qui permet de réaliser une progression de concert satisfaisant ces conditions.
La distance de Fréchet a l'avantage de calculer la distance uniquement sur des couples de points qui auraient pu être mis en correspondance visuellement. La distance de Fréchet est donc très proche d'une distance maximum visuelle entre deux lignes. Hélas, la programmation de cette distance est complexe. Un algorithme d'ordre $O(n.m.\log^2(n.m))$ où n et m sont les nombres de segments des polylignes, est donné dans Alt & Gadau (1995).

La distance de Fréchet discrète

Néanmoins, un algorithme simple (O(n.m)) donnant une approximation discrète de la distance a été proposée dans Eiter & Mannila (1994) pour des couples de polylignes (lignes composées de segments). Si nous notons L_1 et L_2 un couple de polylignes, chacune composée d'une suite ordonnée des extrémités des segments $<u_1 \ldots u_n>$ pour L_1 et $<v_1 \ldots v_m>$

pour L_2, la distance de Fréchet discrète entre L_1 et L_2 $d_{Fd}(L_1, L_2)$ peut se calculer récursivement à partir de la formule suivante :

$$d_{Fd}(L_1, L_2) = \max\left(\begin{array}{l} d_E(u_n, v_m) \\ \min\left(\begin{array}{l} d_{Fd}(<u_1 \ldots u_{n-1}>, <v_1 \ldots v_m>)\{n \neq 1\} \\ d_{Fd}(<u_1 \ldots u_n>, <v_1 \ldots v_{m-1}>)\{m \neq 1\} \\ d_{Fd}(<u_1 \ldots u_{n-1}>, <v_1 \ldots v_{m-1}>)\{n \neq 1, m \neq 1\} \end{array}\right) \end{array}\right)$$

Les suites $<u_1 \ldots u_{n-1}>$ et $<v_1 \ldots v_{m-1}>$ étant des polylignes, il est possible d'appliquer récursivement la distance de Fréchet discrète avec comme paramètre l'une de ces deux lignes. La procédure récursive s'arrête quand les deux lignes sont réduites à deux points. La distance de Fréchet discrète est alors égale à la distance euclidienne.

Intuitivement, cette procédure récursive se traduit de la manière suivante. Pour aller jusqu'aux points u_n et v_m, la longueur de la laisse du chien doit permettre de relier u_n et v_m. Elle est donc supérieure ou égale à la distance entre u_n et v_m. Cette laisse doit aussi permettre d'aller en u_n et v_m en partant de u_1 et v_1. Pour cela, trois solutions (chemins) sont possibles :

- le chien est en v_m et le maître passe de u_{n-1} à u_n ;
- le maître est en u_n et le chien passe de v_{m-1} à v_m ;
- le maître passe de u_{n-1} à u_n et le chien passe de v_{m-1} à v_m en même temps.

L'approximation discrète de la distance de Fréchet peut être utilisée dans le cadre du contrôle qualité car l'erreur engendrée est bornée par la longueur du plus grand segment *(MaxLongSeg)* des deux lignes (Eiter & Mannila, 1994) :

$d_F(L_1, L_2) \leq d_{Fd}(L_1, L_2) \leq d_F(L_1, L_2) + MaxLongSeg$

L'alarme de précision des lignes de côte

Nous allons maintenant voir comment la distance de Fréchet discrète peut être utilisée comme composant d'une alarme de précision pour la ligne de côte. Cette alarme consiste à vérifier si la ligne de côte issue de la carte numérique est cohérente avec celle fournie par l'image radar. Ces deux lignes sont cohérentes si elles sont éloignées d'une distance inférieure à l'erreur maximale tolérée pour la navigation dans cette zone. La distance entre ces deux lignes reflète essentiellement les erreurs d'acquisition, de calage et de discrétisation. Elle traduit la notion suivante : « Plus un navire désire se rapprocher des côtes, plus l'erreur maximale doit être petite ». Pour mesurer l'éloignement des deux lignes, une variante de la distance de Fréchet discrète, la distance de Fréchet discrète partielle (d_{Fdp}), sera employée.

Le processus de l'alarme de précision des lignes de côte peut se décomposer en six étapes (fig. 1). Chaque étape fera l'objet d'une section. Un même exemple permettra de suivre le traitement des lignes de côte pour chaque étape.

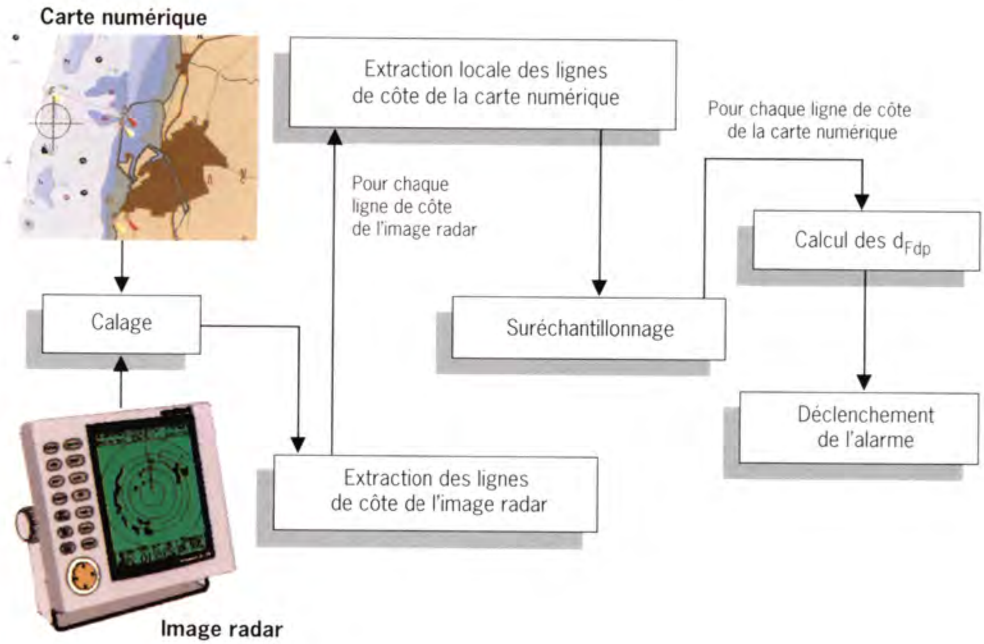


Figure 1
Étapes de l'alarme de précision des lignes de côte.

Le calage de l'image radar et de la carte numérique

La première étape consiste à caler la carte numérique et l'image radar. Pour cela, il faut :
- transformer le positionnement relatif (azimutal et radial) du radar en positionnement absolu sur un géoïde à l'aide d'un dGPS ou d'un GPS ;
- corriger les données des décalages dus aux marées ;
- tenir compte de la distance entre l'antenne GPS et l'antenne radar ;
- convertir le système de référence de la carte numérique s'il est différent de celui du GPS.

L'ensemble de ces outils de calage est indispensable cependant, il faut être conscient qu'ils provoquent des altérations dues aux propriétés des modèles de positionnement et aux approximations. Certaines de ces modifications sont réalisées automatiquement par des systèmes ECDIS.

L'extraction des lignes de côte de l'image radar

Sur l'image radar, les lignes de côte n'existent pas en tant que telles. Seul un ensemble de pixels reflétant la côte (dont la ligne de côte) est disponible. Pour résoudre ce problème, plusieurs algorithmes de conversion d'image matricielle en objets vecteurs ont été proposés (Peuquet, 1981). Hélas, ces algorithmes dégradent la géométrie des objets.

L'extraction des lignes de côte de la carte numérique

La troisième étape consiste à récupérer, pour chaque ligne de côte de l'image radar, les lignes de côte de la carte numérique concernée. Ces lignes sont extraites à partir d'une zone d'emprise (rectangle englobant) de la ligne de côte de l'image radar dilatée de l'erreur tolérée (fonction de l'erreur maximum tolérée et de l'erreur due à la discrétisation). Les lignes de côte de la carte numérique sont celles intersectant le rectangle englobant dilaté. Pour la figure 2, deux fragments de la ligne de côte de la carte numérique sont extraits. Cette extraction permet un filtrage grossier.

Figure 2
Extraction à partir d'un rectangle englobant dilaté.

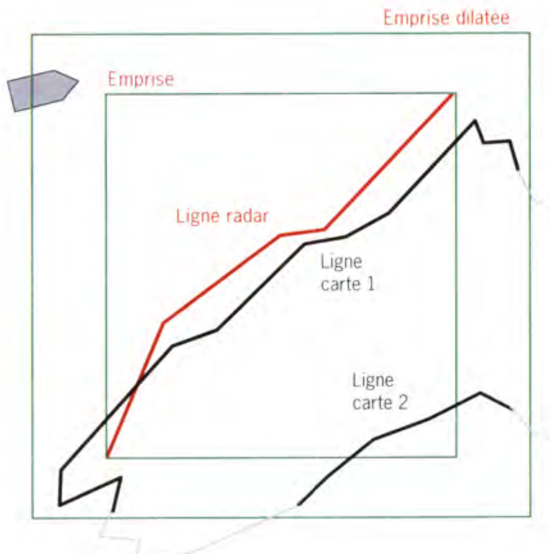
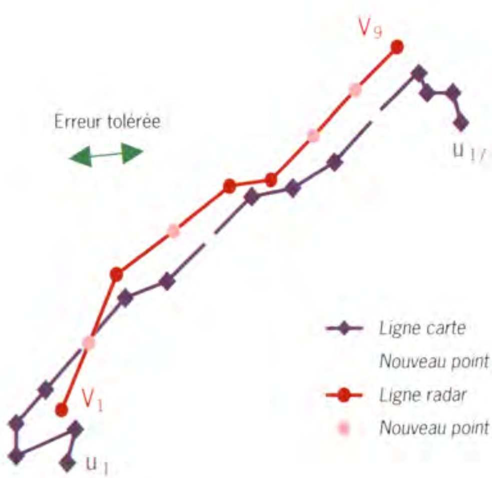


Figure 3
Lignes de la carte numérique et du radar après le suréchantillonnage.



Suréchantillonnage

Pour la distance de Fréchet, l'erreur engendrée par la discrétisation est bornée par la longueur du plus grand segment des deux lignes. Il peut donc être nécessaire de suréchantillonner les lignes (image radar et carte numérique) en rajoutant des points intermédiaires (fig. 3). Les segments seront alors tous de longueur inférieure ou égale à l'erreur tolérée pour le calcul de la distance de Fréchet discrète.

Le calcul de la distance de Fréchet discrète partielle (d_{Fdp})

Le radar ne permet pas d'obtenir une ligne de côte continue. Certaines zones sont masquées par des reliefs. La ligne de côte complète issue de la carte numérique sera donc d'emprise supérieure. Or, les distances sont utilisables uniquement pour mesurer la ressemblance entre une ligne et une autre ligne d'emprise similaire. Pour rendre l'emprise des lignes similaire, l'étape d'extraction des lignes de côte de la carte numérique a permis un premier filtrage grossier. Pour utiliser la distance de Fréchet discrète, cette étape n'est pas suffisante. La distance de Fréchet discrète est égale le plus souvent à la distance euclidienne entre deux extrémités. Pour l'exemple de la figure 3, la distance de Fréchet discrète est égale à la distance entre u_{17} et v_9, ce qui ne correspond pas au résultat d'une mesure intuitive de la ressemblance. Une solution consiste à rechercher une ligne partielle homologue à l'intérieur de la ligne d'emprise supérieure. Une distance de Fréchet discrète pourra alors être mesurée entre la ligne d'emprise inférieure et la ligne partielle homologue. Cette distance sera appelée la distance de Fréchet discrète partielle (d_{Fdp}).

Algorithme de calcul de la distance de Fréchet discrète partielle

Pour calculer la distance de Fréchet discrète partielle et déterminer une ligne partielle homologue, il est nécessaire de détecter automatiquement les points de départ (u_{begin}) et d'arrivée (u_{end}) de la ligne partielle homologue. Ces points sont des points de L_1 (ligne de côte de la carte suréchantillonnée) tels que la distance de Fréchet discrète entre $<u_{begin}...u_{end}>$ et L_2 (ligne de côte de l'image radar suréchantillonnée) homologue soit minimale.

L'ensemble des couples de points (u_i, u_j) de L_1 avec $j \geq i$ sera donc testé par ordre des distances à v_1 pour u_i, des distances à v_m pour u_j afin de déterminer u_{begin}, u_{end} et la d_{Fdp}.

Calcul de la distance de Fréchet discrète partielle pour l'exemple de la figure 3

Pour les deux lignes de la figure 3, premièrement les points candidats vont être détectés. La première et la dernière ligne de la matrice de distance (voir tableau) permettent de définir les listes ordonnées des candidats :

- liste des u_i = { u_2, u_5, u_4, u_1, u_3, ...}, points candidats à u_{begin} ;
- liste des u_j = { u_{14}, u_{15}, u_{16}, u_{13}, ...}, points candidats à u_{end}.

Matrice de distance entre les points des lignes L_1 et L_2 de la figure 3.

		$u_i.x$	4,6	4,8	3,4	3,4	4,1	5,05	6	7	8	9	10	11	12	13	13,2	13,8	14
		$u_i.y$	1,6	2,6	1,8	2,8	3,8	5,15	6,5	7	8,25	9,5	9,75	10,5	11,9	13,2	12,6	12,6	11,7
$v_j.x$	$v_j.y$		u_1	u_2	u_3	u_4	u_5	u_6	u_7	u_8	u_9	u_{10}	u_{11}	u_{12}	u_{13}	u_{14}	u_{15}	u_{16}	u_{17}
4,5	3,2	v_1	1,6	0,67	1,78	1,17	**0,72**	2,03	3,62	4,55	6,14	7,74	8,55	9,77	11,5	13,1	12,8	13,2	12,7
5,15	5,2	v_2	3,64	2,62	3,82	2,97	1,75	**0,11**	1,55	2,58	4,17	5,77	6,65	7,89	9,58	11,2	10,9	11,4	11
5,8	7,2	v_3	5,73	4,71	5,91	5,01	3,8	2,18	**0,73**	**1,22**	2,44	3,94	4,91	6,16	7,78	9,37	9,16	9,65	9,35
7,15	8,5	v_4	7,36	6,35	7,68	6,82	5,6	3,95	2,31	1,51	**0,89**	2,1	3,11	4,34	5,92	7,5	7,31	7,81	7,56
8,5	9,8	v_5	9,08	8,1	9,49	8,66	7,44	5,79	4,14	3,18	1,63	**0,58**	1,5	2,6	4,08	5,64	5,47	5,99	5,82
9,5	10	v_6	9,72	8,77	10,2	9,44	8,22	6,58	4,95	3,91	2,3	0,71	**0,56**	1,58	3,14	4,74	4,52	5,02	4,81
10,5	11,3	v_7	11,4	10,4	11,9	11,1	9,86	8,22	6,58	5,54	3,94	2,34	1,63	**0,94**	1,62	3,14	3	3,55	3,52
11,5	12,7	v_8	13,1	12,1	13,6	12,8	11,6	9,93	8,29	7,26	5,66	4,06	3,31	2,26	**0,94**	1,58	1,7	2,3	2,69
12,5	14	v_9	14,7	13,8	15,2	14,4	13,2	11,6	9,92	8,9	7,3	5,7	4,93	3,81	2,16	**0,94**	1,57	1,91	2,75

Deuxièmement, les d_{Fd} entre les lignes <u_i…u_j> et L_2 vont pouvoir être calculées, dans l'ordre des candidats à u_{begin}, puis dans l'ordre des candidats à u_{end} :

• La première d_{Fd} calculée sera d_{Fd}(<u_2…u_{14}>, L_2). Elle renverra 1,78 ($d_E(u_3,v_1)$) comme d_{Fd}. Cette valeur ainsi que u_2 et u_{14} seront retenues comme résultat intermédiaire. La seconde distance calculée, d_{Fd}(<u_2…u_{15}>, L_2), renverra le même résultat. Les d_{Fd} avec les u_j suivants ne seront pas calculées car, $d_E(u_j,v_9)$ étant supérieure à 1,78 quel que soit u_j, la d_{Fd} sera donc forcement supérieure au résultat intermédiaire.

• Nous pouvons passer au deuxième candidat pour u_{begin} : u_5. d_{Fd}(<u_5…u_{14}>,L_2) sera la première distance calculée. Elle renverra 1,22 qui est égale à $d_E(u_8,v_3)$. Cette valeur ainsi que u_5 et u_{14} seront retenues comme résultat intermédiaire. Un chemin permettant d'obtenir cette d_{Fd} est fourni par les cellules en caractères gras dans le tableau. Les d_{Fd} avec les u_j suivants ne seront pas calculées car $d_E(u_j,v_9)$ est supérieure à 1,22 quel que soit u_j.

• Nous pouvons passer au troisième candidat pour u_{begin} : u_4. Les distances calculées, quel que soit u_j, ne changeront pas le résultat intermédiaire ;

• Les candidats suivants pour u_{begin} (u_1, u_3) ne seront pas testés car la distance euclidienne entre ces points et v_1 est supérieure à 1,22.

La ligne partielle homologue est donc <u_5…u_{14}> et la distance de Fréchet discrète partielle associée est de 1,22.

Ce calcul doit être réalisé pour chaque ligne extraite de la carte numérique. Comme il est impossible de savoir si L_2 et L_1 ont une orientation compatible, il faut calculer la distance de Fréchet discrète partielle entre L_2 et L_1 et entre L_2 et L_1 inversée (<u_n…u_1>). La mesure associée à chaque L_2 sera le minimum des d_{Fdp} obtenues.

Déclenchement de l'alarme

Si, pour une ligne de côte de l'image radar, il n'existe pas de ligne de côte de la carte numérique telle que la d_{Fdp} de ce couple soit inférieure à l'erreur maximale tolérée, il faut déclencher l'alarme de précision.

Cette dernière peut être visuelle ou sonore. Elle peut par exemple faire clignoter la ligne de côte de l'image radar et la ligne de côte partielle de la carte numérique la plus proche. Le couple de points (u_i, v_j) où la d_{Fdp} est obtenue peut aussi être visualisé. Pour l'exemple de la figure 3, si l'erreur maximale tolérée est inférieure à la $d_{Fdp}(1,22)$, l'alarme sera déclenchée.

Conclusion

Cet algorithme a été codé en *C++* et testé sur une Sun Ultra 5. Une ligne de côte (1935 points ou 34 km) issue d'une carte Shom à l'échelle du 1/20 000 de la région de la pointe du Raz (Finistère, France) a été utilisée comme jeu de données test. Les fragments de la ligne de côte de l'image radar ont été simulés à partir de la première ligne. La position de chaque fragment a été biaisée et bruitée aléatoirement. Le temps de calcul des distances de Fréchet discrètes partielles est de l'ordre de cinq secondes, ce qui est compatible avec son utilisation en tant qu'alarme à bord d'un navire associé à un radar.

Cet algorithme peut être utilisé pour les traits de côte du continent et la grande majorité des îles. Cependant, pour de petites îles, l'étape d'extraction des lignes de côte de la carte numérique risque de renvoyer une ligne fermée sans relation d'ordre sur les points (ordre cyclique). La distance de Fréchet discrète doit alors être adaptée.

Cet article a permis de concevoir une nouvelle alarme de précision pour les lignes de côte. Dans cet objectif, la distance de Fréchet discrète partielle mesurant l'écart entre deux lignes d'emprise différente a été définie. Elle autorise aussi la détection des lignes partielles homologues. Les incohérences entre la représentation cartographique et l'image radar sont ainsi décelées. Cependant, la source de l'erreur (GPS, radar, carte numérique) n'est pas fournie. Les opérateurs doivent donc connaître les mesures appropriées à prendre lorsqu'un écart se présente. L'algorithme de la distance de Fréchet discrète partielle ainsi défini peut aussi être réutilisé pour apparier d'autres objets linéaires d'emprise différente (tronçons de route à différentes échelles...).

Les premiers résultats permettent d'envisager de tester cet outil en situation réelle. Cette implémentation va rendre les systèmes de navigation plus sûrs en fournissant un contrôle embarqué de la précision géométrique des lignes de côte. Elle autorisera aussi une meilleure interconnexion entre le radar, le dGPS et l'ECDIS, ce qui va dans le sens des serveurs de données d'environnement global (Le Gouic, 1998).

Références bibliographiques

Alt H., Gadau M., 1995. Measuring the resemblance of polygonal curves. 8th Annu. ACM Symposium on Computational Geometry, 102-109.

Botton S., 1996. Le Système GPS : une révolution en matière de positionnement. Rev. Intern. Géomatique, 6(2-3), 271-279.

Devogele T., 1997. Processus d'intégration et d'appariement de bases de données géographiques, application à une base de données routières multi-échelles. Thèse d'informatique, université de Versailles.

Eiter T., Mannila H., 1994. Computing Discrete Fréchet Distance. Rapport technique Christian Doppler Labor für Expertensensysteme, Université technique de Vienne, CD-TR 94/64.

Goodyear J., Rae A., 1996. Confined waterways - a challenge. Canadian Hydrographic Service, Contour Magazine, autumn.

IHO, 1996. IHO transfer standard for digital hydrographic data. Edition 3.0, November, Special Publication, Intern. Hydrogr. Org., Monaco, 57.

IMO, 1996. Code on Alarms and Indicators. International Maritime Organization Performance Standards for ECDIS (Appendix 5), num. IMO-867E.

ISO, 1994. Norme ISO 8402 : Management de la qualité et assurance de la qualité.

Le Gouic M., 1998. Cartes marines électroniques et données d'environnement maritimes numériques. Rev. Navigation, 46(181).

Peuquet D., 1981. An examination of techniques for reformatting digital cartographic data. Part 1: The raster to vector process. Cartographica, 18, 34-48.

Proteau J., 1995. ECDIS and the ocean. Canadian Hydrographic Service. Contour Magazine, summer.

Sletto LTJG, 1996. Putting new navigation system to the test. Canadian Hydrographic Service. Contour Magazine, autumn.

Chapitre 3

Environmental and resource applications

Applications à l'environnement et aux ressources

Perspectives offertes par la communication entre un modèle hydrodynamique et un SIG pour l'aide au diagnostic environnemental. Caractérisation de la dynamique et de la qualité des masses d'eaux côtières

Lionel Loubersac[(1)], Jean-Claude Salomon[(1)], Marguerite Breton[(1)], Christophe Durand[(2)], Caroline Gaudineau[(3)]

(1) Ifremer Brest, Del/ao, BP 70, 29280 Plouzané, France - lloubers@ifremer.fr

(2) Ifremer Brest, Dnis/esi, BP 70, 29280 Plouzané, France

(3) Institut national agronomique Paris-Grignon, 16 rue Claude Bernard, 75231 Paris Cedex 05, France

Résumé

On présente un ensemble de solutions utilisables pour l'aide au diagnostic en matière d'aménagement et gestion intégrée de la qualité des eaux côtières basées sur la communication entre un modèle hydrodynamique et un SIG. On décrit les fonctionnalités de l'interface informatique développée sous ArcView (ESRI) qui permet d'assurer la communication opérationnelle des données issues du modèle vers le SIG, sous forme vecteur ou raster. Les applications choisies traitent de la simulation de la dynamique spatio-temporelle de masses d'eaux et de l'identification de zones fragiles qu'elles peuvent atteindre. Les exemples considèrent un site du littoral français soumis à de fortes pressions d'exploitation humaine qui sont directement dépendantes de la qualité des eaux. En conclusion, on discute des atouts et des limites de la mise en synergie des deux outils. On aborde également les perspectives d'élaboration de bases de données géographiques, utilisables dans une optique d'aide à la décision à partir de synthèses représentatives de l'hydrodynamisme d'un espace côtier.

Abstract

This paper presents a set of solutions based on the synergy between GIS and a numerical model to help in diagnosis and decision making for water quality related matters. After an overview of the model features, it describes the computer interface (ModelView) implemented as an extension of the Arc View (ESRI) GIS System to provide operational data communication between the model and the GIS in vector or raster form. The paper particularly focuses on changes in the quality of coastal waters from river discharges. It looks at the spatio-temporal representation of this behaviour and the spatial analysis of sensitive areas

that can be impacted. Examples are given of a French coastal area subject to strong human pressure, *i.e.* marine cultures and recreational activities that are directly dependent on coastal water quality. The interest in establishing synergy between numerical models and GIS is discussed in the conclusion, based on the specific situations given as examples. Prospective development of general geographic databases providing representative coastal area hydrodynamics synthesis for decision making support is also examined.

Introduction

La compréhension et la représentation de la dynamique et du devenir en mer des masses d'eaux d'origine continentale sont fondamentales pour toute approche intégrée d'aménagement des zones côtières. Cette problématique intéresse directement l'étude des impacts et risques engendrés par la dégradation de la qualité des eaux sur les ressources et activités.

Les outils de modélisation mathématique de l'hydrodynamique côtière sont particulièrement adaptés à la fourniture théorique (simulations) de connaissances des grandeurs physiques : hauteurs d'eau, courants, dispersion, houles..., dans les quatre dimensions (x, y, z et t). Un SIG est pour sa part, et par construction, apte à décrire et à manipuler des données réelles, géoréférencées dans les trois dimensions (x, y, z). La mise en communication de ces outils apparaît particulièrement utile compte tenu de leur complémentarité. Le modèle permet de décrire et de prédire le comportement, en théorie pour tout pas de temps, d'un système dynamique, caractéristique de l'environnement littoral. Le SIG est apte à gérer des données géocodées, la bathymétrie par exemple, en entrée du modèle, ou bien en sortie pour la présentation de ses résultats. Il offre en outre des possibilités d'analyse spatiale par la mise en conformité géographique des « couches » d'information issues d'un modèle avec celles provenant de base de données géographiques conventionnelles.

Plusieurs travaux, en Europe notamment, ont été menés sur le sujet. Les premiers exemples en Allemagne pour la mer de Wadden ont montré les complémentarités entre le SIG Arc/Info et deux modèles mathématiques : Hiswa pour la houle et les vagues et Trisula pour les hauteurs d'eaux et les courants de marée. Au Danemark, le Danish Hydraulic Institute (Andersen, 1996 et 1997) a développé un outil d'aide à l'aménagement du littoral basé sur la connexion entre deux modèles mathématiques : Litpack (Foster & Skou, 1992) et Mike 21 (Warren & Bach, 1992) avec le SIG ArcView. En France, l'Ifremer développe un programme qui vise à doter ses laboratoires côtiers d'outils d'aide au diagnostic.

Ceux-ci s'articulent autour de la mise en communication de modèles hydrodynamiques et de SIG tels que décrits ci-après. Ce programme résulte, d'une part, d'un travail conceptuel puis de mise en œuvre de modélisation de l'hydrodynamique côtière (Salomon 1994 ; Salomon *et al.*, 1995 ; Garreau & Bailly Du Bois, 1996 ; Lazure & Jegou, 1998), d'autre part, de travaux méthodologiques qui font appel à l'information géographique et aux SIG comme outils d'aide à l'aménagement et à la gestion du littoral (Loubersac *et al.*, 1997 ; Populus *et al.*, 1997). On trouvera, dans les paragraphes qui suivent, une discussion et des exemples d'application de la mise en synergie de ces outils sur la zone géographique « La Rochelle-La Tremblade » du Centre-Ouest atlantique français.

Matériel et méthodes

Le système d'information et d'aide au diagnostic est composé de trois éléments fondamentaux :
- un modèle numérique hydrodynamique : Mars ;
- un logiciel de SIG : ArcView d'ESRI et ses extensions ;
- une base de données géoréférencées.

Le modèle hydrodynamique Mars

Il s'agit d'un algorithme de calcul des courants marins, des hauteurs d'eau, et des concentrations en éléments solubles (ou en suspension temporaire) transportés par les courants. Mars est composé de :
- un noyau de calcul opérationnel en version 2D et 3D ;
- un pré-processeur nommé IMars dont les fonctions essentielles sont la gestion et l'intégration aisées des paramètres et données d'entrée qui servent à l'activation du code de calcul ;
- un programme d'exploitation graphique des résultats nommé VisuMars qui permet, pour les utilisateurs de Mars qui ne possèdent pas d'interface avec le SIG ArcView de présenter les résultats de calculs sous forme de courbes et de cartes.

Caractéristiques du programme Mars

Mars effectue les calculs hydrodynamiques dans un écoulement liquide plan, quasi horizontal. La forme des fonds peut être absolument quelconque et comporter un nombre quelconque de chenaux, îles, hauts-fonds, bancs découvrants et estrans. Il permet de modéliser sous forme de calculs instantanés ou de synthèses (valeurs moyennes, maxima, minima...) les grandeurs suivantes :
- le courant (composantes U et V) et les résiduelles eulériennes ;
- la hauteur du plan d'eau, les niveaux moyens et les composantes harmoniques de marée ;
- la salinité ;
- des constituants provenant de rejets (dans les exemples qui suivent, les coliformes fécaux) ;
- le transport sédimentaire et les dépôts.

Il produit, pour chaque zone étudiée, une base de données dont les résultats sont stockés sous forme d'une série temporelle de vecteurs et de scalaires en coordonnées géographiques. On se limitera dans ce qui suit à la description puis aux applications de la version 2D du modèle.

On démontre que les calculs réalisés par le modèle nécessitent l'utilisation de trois types d'information :
• La topographie du domaine (fournie ici par une matrice des profondeurs);
• Les conditions aux limites sur les frontières ouvertes du domaine;
• Les flux d'eau et de matière dissoute (ou en suspension) à l'intérieur du domaine (rivières, émissaires...).
Les hypothèses du calcul valables en 2D sont les suivantes :
- la composante horizontale du courant ne varie pas beaucoup depuis la surface jusqu'à proximité du fond (courant de masse). Le modèle dans sa version 2D calcule la moyenne des courants sur la verticale et cette valeur moyenne a une forte signification physique;
- les vitesses verticales sont faibles.
Sous ces hypothèses, les lois qui décrivent le comportement physique du système, à savoir le second principe de Newton et la loi de conservation de la masse, se traduisent par le système d'équations dit de Saint-Venant. Ce système est complété par l'équation de transport-diffusion-décroissance d'un élément chimique (ou assimilé) transporté en suspension. Mars intègre ces équations différentielles de manière totalement automatique, quelle que soit la forme du domaine, qui peut d'ailleurs évoluer dans le temps (zones découvrantes, murs immergés, etc.).

Intégration numérique, conditions aux limites et emboîtement des modèles

Dans un souci de meilleure précision, de minimisation des temps de calcul et de facilité d'emploi, on adopte une méthode en différences finies sur un maillage régulier. Pour offrir une représentation de la réalité d'autant plus fine et précise que l'on se situe sur la zone d'intérêt, le modèle Mars utilise une technique d'emboîtement de modèles sous forme gigogne. Par cette technique, un modèle de grande emprise et de grande maille contient lui-même un ou plusieurs sous-modèles (loupes). Ces derniers reçoivent, des modèles qui les précèdent, les conditions aux limites sur leur périmètre. Dans le cas des exemples présentés, le modèle de grande emprise s'étend jusqu'au plateau continental et trouve ses conditions aux limites dans la valeur des ondes générant la marée au large. Un forcing météorologique peut être pris en compte sur toute la surface du modèle et ses éventuelles loupes successives. On se reportera à Salomon & Breton (1998) pour l'explicitation de la méthode d'intégration et de définition des maillages de calcul.

L'interface de communication entre Mars et ArcView : ModelView

Objectif de ModelView

L'objectif principal de ModelView est de faciliter l'import par le Système d'information géographique (SIG) ArcView des données générées par le modèle hydrodynamique Mars afin de les intégrer directement en conformité géographique dans une base de données géoréférencées, (Durand *et al.*, 1998).

Principales fonctionnalités

ModelView permet :
- d'ouvrir une base de résultats de Mars et de lister les objets issus de simulations ;
- de sélectionner la projection et le format géodésiques souhaités pour les données importées ;
- de sélectionner le constituant modélisé, l'heure du résultat, la résolution spatiale ;
- d'importer les résultats produits par le modèle sous la forme d'une image au format Grid (concentration en éléments dissous par exemple) ou sous la forme d'une couverture de points au format Shape d'ArcView (vitesse et direction des courants par exemple) ;
- de limiter l'import à une zone d'intérêt définie à l'écran ;
- d'exporter automatiquement des séries de vues ou de mises en pages cartographiques pour permettre la réalisation de séquences animées.

Base de données géoréférencées intégrées au système

Spécifications des données de base

Le système est conçu pour intégrer les données issues du modèle au sein d'une base d'information géographique permettant : a) les habillages des résultats du modèle, b) des analyses spatiales entre ces résultats et des informations extérieures. L'objectif du projet étant de caractériser les espaces côtiers soumis à des dégradations potentielles de la qualité des eaux dont l'origine provient généralement de sources continentales, c'est un référentiel cartographique terrestre plutôt que maritime qui a été adopté (système Lambert II étendu), en cohérence avec les choix des services techniques de l'État qui travaillent avec l'Ifremer (Affaires maritimes, Équipement, Environnement, Santé...).

Données géoréférencées intégrées dans le système

Elles comprennent des données dites de référence de niveau 1 ou 2 (Allain *et al.*, 1999). On trouve ainsi :
- les fonds cartographiques IGN Scan25 et 100, ainsi que Shom 1/150000 qui résultent de la scannérisation des feuilles topographiques IGN ou hydrographiques du Shom ;
- le fond topographique BD Carthage des agences de l'Eau et du ministère de l'Environnement, dérivé des fonds IGN BD Carto, utilisable à des échelles inférieures ou égales au 1/100000 qui comprend les limites administratives, les réseaux, l'hydrographie zonale...
- le fond hydrographique BD Sigma du Shom utilisable à des échelles inférieures ou égales au 1/50000 et résultat de la numérisation des objets géographiques des cartes marines. Il contient les objets : sondes, isobathes, balisage, épaves...
- des orthophotographies aériennes qui proviennent de missions effectuées à marée basse au 1/10 000 en noir et blanc par l'Ifremer pour les opérations d'évaluation des stocks et par le Shom au 1/20000 en couleur, pour l'élaboration de la BD PS ;

- des images de la télédétection aérospatiale telles que des données Spot acquises en mode P et/ou XS à plusieurs dates ;
- des données d'occupation du sol : Corine Land Cover et données de l'Ipli ;
- les levés de bathymétrie fine et de balisage ostréicole réalisés par l'Équipement (service maritime) limités à l'altitude approximative de 4 m au-dessus du zéro hydrographique ;
- le cadastre ostréicole numérisé issu de feuilles gérées par les quartiers des Affaires maritimes ;
- les points de rejets : émissaires principaux ou secondaires caractérisés par l'information disponible sur leurs débits et flux de matière polluante ;
- des données relatives à la qualité du milieu issues des réseaux de suivi de la qualité du milieu marin (RNO, Rémi et Réphy) gérés dans la base de données Quadrige de l'Ifremer ou de réseaux DDE/Cqel ou Ddass (qualité des eaux de baignade) ;
- l'emprise des usages sensibles aux modifications de qualité des eaux côtières, en particulier les cultures marines ;
- les réglementations (Guillaumont *et al.*, 1999), notamment celles relatives au classement en zones de salubrité, d'autorisation de rejets, de régulation des usages sensibles évoqués plus haut ou de protection d'habitats naturels ;
- les productions conchylicoles originaires des stations côtières de l'Ifremer ;
- les milieux naturels sensibles : habitats critiques, nourriceries, frayères, gisements naturels.

On se reportera à Loubersac *et al.* (1997) et Populus *et al.* (1997) pour ce qui concerne les outils et méthodes mis en œuvre pour le géoréférencement et la mise en conformité de données géocodées listées ci-dessus.

Résultats et applications

Habillage des résultats du modèle

La première fonctionnalité de la mise en communication entre modèle et SIG concerne la présentation des résultats de la modélisation. L'objectif est :
- d'aider à mieux faire comprendre les phénomènes et leur dynamique spatiale et temporelle (fig. 1) ;
- d'élaborer un outil d'aide à l'interprétation scientifique des situations en mettant en relation les résultats simulés et ceux d'observations réelles (télédétection) dans des conditions équivalentes (fig. 2).

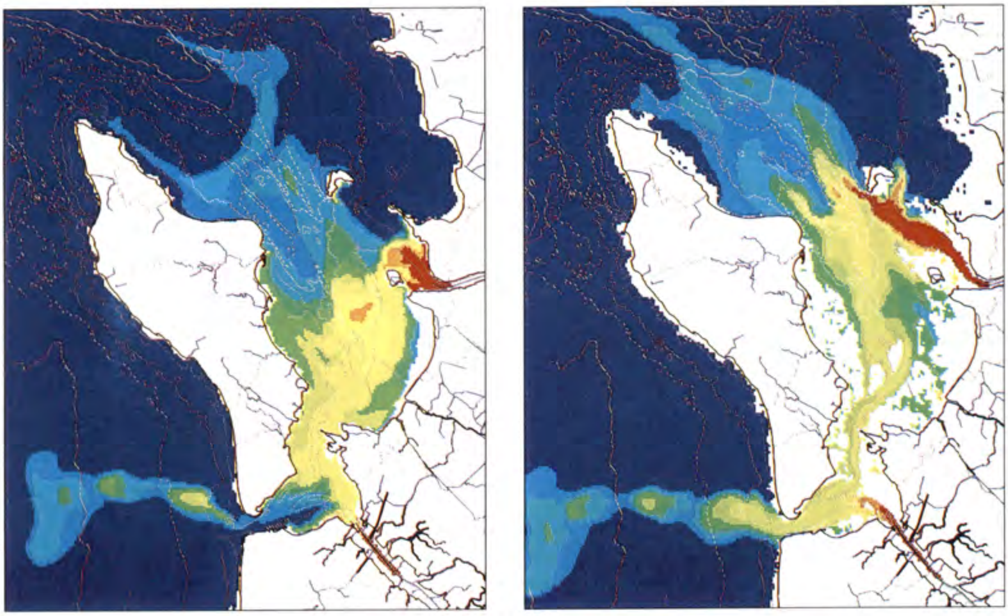


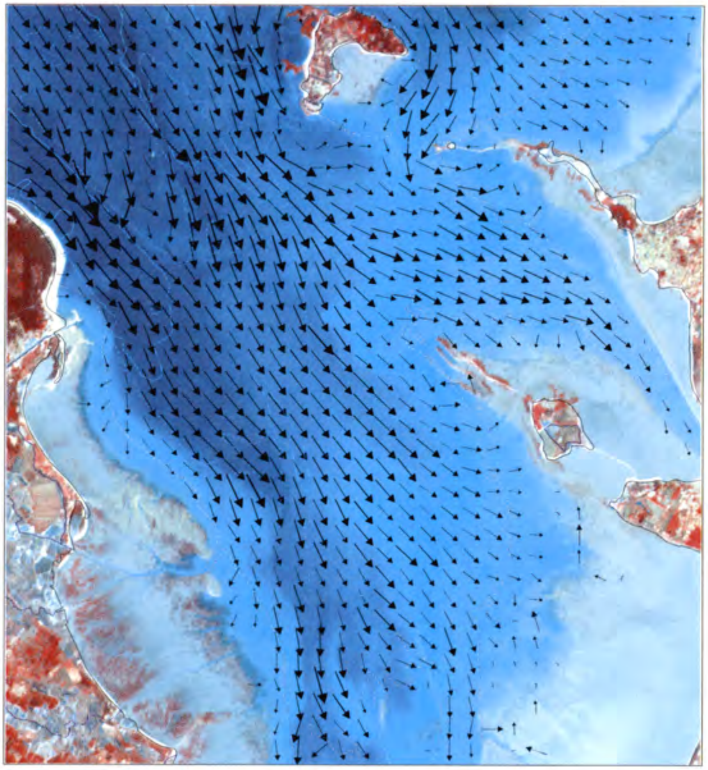
Figure 1
Région sud de La Rochelle : extension instantanée en mer des rejets de la Charente (100 m³/s), de la Seudre (10 m³/s) et du chenal de Brouage (1 m³/s). Coefficient de marée 110, 600 heures de simulation. À gauche, situation de haute mer, à droite, situation de basse mer. Le paramètre modélisé est ici la salinité qui est croissante du rouge au bleu. Le fond cartographique de référence est issu de la mise en relation de données de la BD Carthage (AE/MATE) et de la BD Sigma (Shom).

Surveillance de la qualité du milieu et caractérisation de zones sensibles

On développe dans ce paragraphe deux applications.

La première (fig. 3 et 4) est théorique et fait référence à l'étude d'une situation de risque de contamination microbiologique majeure des eaux aux environs des fêtes de fin d'année, en période de commercialisation massive de produits de la mer (huîtres). Elle prend le cas d'une crue hivernale du fleuve Charente (400 m^3/s) d'une durée de 15 jours simultanée à la présence de concentrations de bactéries dans l'effluent cohérentes avec des mesures en coliformes fécaux effectuées à l'émissaire par les services de la Santé. Le T90 (temps au bout duquel 90 % des bactéries ont disparu en mer) est déduit des conditions d'éclairement solaire et de turbidité des eaux pour la période (Guillaud *et al.*, 1997). Le modèle exprime les concentrations en bactéries sur une échelle logarithmique sous une forme synthétique qui correspond à la moyenne de l'ensemble des situations instantanées calculées sur la période. On convertit alors ce champ moyen de concentration en coliformes dans l'eau en équivalent de concentration dans la matière vivante (bivalves filtreurs) par application d'un facteur de concentration issu d'expérimentations (Deslou Paoli *et al.*, 1987). Le résultat obtenu est ensuite hiérarchisé conformément aux normes de classement de salubrité actuellement adoptées en France (fig. 3).

Figure 2
Région de l'île d'Aix, au sud de La Rochelle : champs de courants de marée instantanés modélisés et reportés sur des images géoréférencées SPOT XS (CNES 93-96) acquises dans des situations équivalentes aux simulations. En haut, situation de basse mer + 1h (coeff 79), en bas, situation de basse mer - 1h (coeff 90).



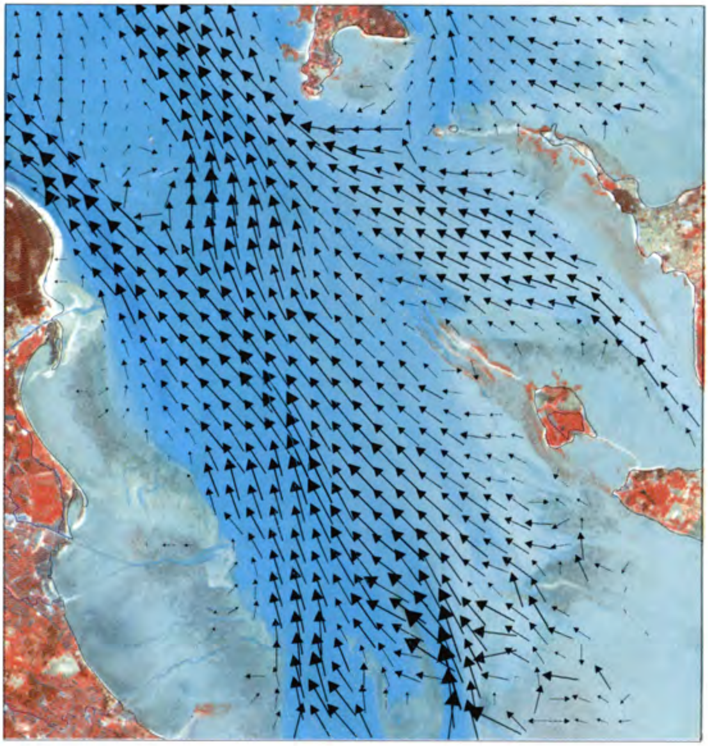


Figure 3
Concentration en coliformes fécaux convertie et normalisée en équivalent de concentration dans la matière vivante. Les couleurs correspondent aux classes de concentration en nombre de coliformes pour 100 ml de chair et liquide intervalvaire (ChLI) : en bleu absence, en vert moins de 300 en bistre de 300 à 1 000, en orange de 1 000 à 6 000, en rouge de 6 000 à 60 000, en noir pas de données. On a reporté sur cette figure la position des différents points de mesure des réseaux de surveillance microbiologique de l'Ifremer, de la DDE/Cqel et de la Ddass, le réseau hydrographique et les limites administratives.

Enfin, sur la figure 4, on présente un zoom de la partie médiane de la figure précédente sur lequel on situe l'emprise des zones de cultures marines et des parcelles ostréicoles en relation avec les classes de contamination. Sur cette figure, on identifie les zones salubres, de couleurs bleue et verte, de celles (bistre, orange ou rouge) susceptibles d'être contaminées par les bactéries qui présentent donc un risque potentiel au plan de la commercialisation des produits de la mer.

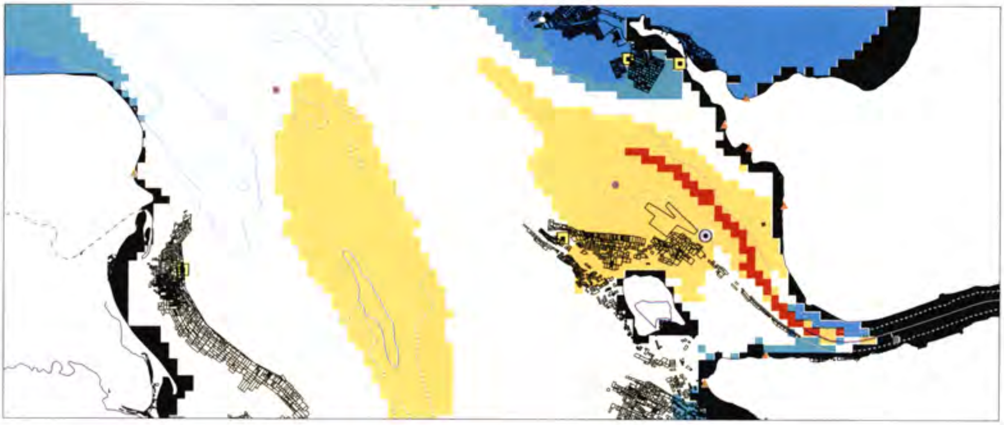


Figure 4
Partie centrale du bassin ostréicole de Marennes-Oléron. Mise en relation de l'emprise des concessions ostréicoles (limites du parcellaire en noir) avec les classes de contamination correspondant à la figure 3. La partie terrestre est en blanc.

La seconde application fait référence à l'analyse de l'impact potentiel des modifications quantitatives des flux d'eau douce dans le bassin ostréicole de Marennes-Oléron en période d'étiage du fleuve Charente. Dans cette région, compte tenu d'un développement très important de l'agriculture irriguée sur le bassin versant depuis une dizaine d'années, le débit d'étiage du fleuve est tombé d'une douzaine de mètres cubes par seconde à environ cinq mètres cubes par seconde. Il en résulte des perturbations de la capacité trophique du bassin ainsi que la mise en évidence d'anomalies dans le captage du naissain d'huîtres lors des périodes d'étiage où le débit est particulièrement faible. Une partie importante du captage s'effectue dans des zones où les chocs de salinité en été sont atténués et où un apport d'eau douce reste significatif, par exemple celles proches de l'embouchure du fleuve. Dans cette application, on a simulé par modélisation l'extension du panache d'eau douce dans deux cas qui correspondent à la période d'étiage entre mi-juin et mi-juillet pour des débits moyens de 5 m^3/s et 12 mètres cubes par seconde. Afin de s'affranchir des variabilités spatio-temporelles de l'extension des eaux douces en mer on a, à l'instar de ce qui a été présenté précédemment, produit une synthèse sur la période d'étiage qui correspond à la moyenne des salinités instantanées obtenues dans chaque maille du modèle. Par la suite, on a intégré la localisation des aires de captage de naissain d'huîtres avec les résultats simulés (fig. 5).
La comparaison des deux situations présentées en figure 5 permet de constater les différences d'extension du panache en mer, notamment vers le sud, mais aussi en proche sortie d'estuaire. L'utilisation de fonctions d'analyse spatiale sous SIG (extension Spatial Analyst d'ArcView) permet d'établir que, dans la situation d'un débit d'étiage de 12 m^3/s, 507 h de zones de captage se situent dans la zone de salinité moyenne comprise entre 33,5 et 34,5 pour mille. Dans la situation d'un débit de 5 m3/s, cette surface se réduit à 232 hectares.

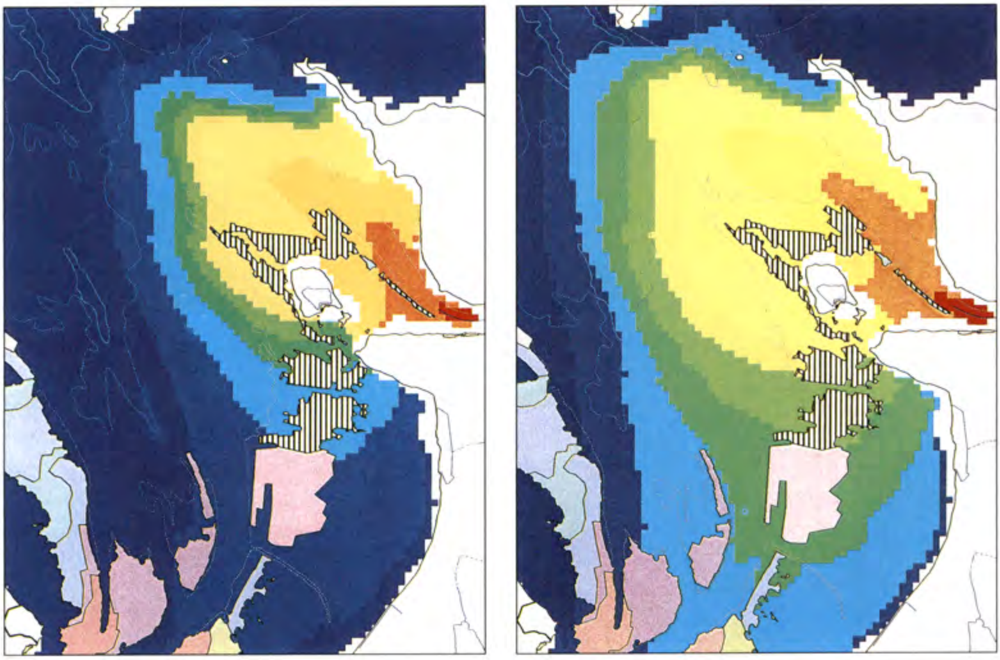


Figure 5
Comparaison de l'extension du panache de dessalure à l'embouchure du fleuve côtier Charente, à gauche, débit de 5 m^3/s, à droite, de 12 mètres cubes seconde. Les zones de captage sont représentées par des hachures foncées verticales, la salinité va croissant du rouge vers le bleu. La partie terrestre est en blanc.

Conclusions et perspectives

Ce papier a succinctement présenté les méthodes et outils en cours de développement à l'Ifremer qui assurent la communication entre les données produites par la modélisation et celles gérées par un SIG. Les applications intéressent directement plusieurs problématiques d'aménagement du littoral posées dans le cadre de la surveillance de la qualité du milieu et l'étude des impacts sur les ressources et les usages, ainsi :
- l'analyse du positionnement adéquat des points de surveillance et de la fréquence d'observation, sujet qui touche aussi bien l'optimisation des protocoles de mesures que la représentativité de ces dernières ;
- l'aide à l'identification et à la caractérisation de zones soumises à risque de contamination ou à dysfonctionnement en conditions particulières.
Les bénéfices issus de la mise en synergie des modèles et des SIG sont donc importants en matière de représentation, communication et explicitation de l'information. Cependant, parmi les difficultés qui restent posées, on peut dégager deux axes qui se basent sur le fait qu'intrinsèquement les SIG ne possèdent encore que des pseudo-fonctions d'analyse 3D et maîtrisent mal l'information dynamique.
Le premier axe concerne les développements de la modélisation 3D. Celle-ci est désormais suffisamment mûre au plan méthodologique pour passer dans le domaine des applications opérationnelles. Par contre, la mise en communication des données de ce type de modélisation et des SIG se heurte aux capacités réduites des principaux produits SIG du

marché qui proposent généralement des fonctions pour manipuler des vecteurs 3D, mais pas des mailles 3D composées de voxels (volumes éléments).

Le second axe concerne la communication opérationnelle vers les SIG de données synthétiques issues des modèles. De manière à contourner la faiblesse des SIG à traiter des grandeurs qui sont fonction du temps, l'idée est de générer des synthèses temporelles (et non une série de caractéristiques instantanées) qui peuvent, grâce aux fonctionnalités de communication entre modèles et SIG, entrer dans la constitution de bases d'information géographique côtière. Parmi les paramètres synthétiques utilisables comme indicateurs représentatifs de l'hydrodynamisme d'une région d'étude, on identifie, outre la représentation « statistique » de l'extension en mer d'un effluent et des fonctions de transfert entre un point de rejet et un point quelconque au large, les facteurs suivants :

- les champs de courants maximaux de marée ;
- un indice représentatif de la capacité dispersive liée aux courants ;
- un indice de stratification ;
- les résiduelles lagrangiennes ;
- les trajectoires ;
- les temps de résidence des masses d'eau...

Pour l'un ou l'autre des axes prospectifs considérés plus haut, l'évolution des traitements 3D sous SIG et l'élaboration de synthèses issues de la modélisation, la nature des outils devient de plus en plus complexe. Elle oblige l'utilisateur des SIG à développer des connaissances toujours plus fines pour mieux traiter les données et communiquer des résultats pertinents.

Une partie des développements méthodologiques et des travaux de structuration de l'information géographique sur la zone atelier de Marennes-Oléron-Brouage a bénéficié du support financier du Programme national de recherches sur les zones humides (PNRZH) du ministère de l'Environnement, des agences de l'Eau et du GIP Hydrosystèmes dans le cadre du projet Aramis.

Références bibliographiques

Allain S., Guillaumont B., Le Visage C., Loubersac L., Populus J., 1999. Données géographiques de référence en domaine littoral. *In:* CoastGIS'99, Brest, sept. 1999, Éd. Ifremer, Actes Colloq., 25, 67-79.

Andersen R., 1996. Eagle, a GIS for environmental impact assessment. *In:* Geographical information, from research to application through cooperation. I, 310-317. IOS Press, Amsterdam.

Andersen R., 1997. Mike Info/coast, a GIS based tool for coastal zone management. *In:* CoastGIS'97, Proc. 2nd Intern. Symp. on GIS and computer mapping for coastal zone management. University of Aberdeen, Scotland, August 1997.

Deslou Paoli M., Héral M., Goulletquer P., Boromathanarat W., Razet D., Garnier J., Prou J., Barillet L., 1987. Évolution saisonnière de la filtration des bivalves intertidaux dans des conditions naturelles. Océanis, 13(4-5), 575-579.

Durand C., Loubersac L., Massé J., 1998. Operational GIS applications at the French oceanographic research institute Ifremer. ESRI International Users Conference, July, San Diego, USA.

Foster T.M., Skou A.J., 1992. Litpack, an integrated modelling system for littoral processes and coastline kynetics. 3rd International exhibition for environmental science and engineering. Como, Italy.

Garreau P., Bailly Du Bois P., 1996. Transportation of radionuclides in Celtic Sea. A possible mechanism. Radioprot., 32(C2), 381-385.

Guillaud J.-F., Derrien A., Gourmelon M., Pommepuy M., 1997. T90 as a tool for engineers : interest and limits. Wat. Sci. Tech., 35(1112), 277-281.

Guillaumont B., Durand C., 1999. The integration and management of regulatory data in a GIS: an applied analysis of the French coasts. *In:* CoastGIS'99, Brest, sept. 1999, Éd. Ifremer, Actes Colloq., 25, 269-283.

Lazure P., Jegou A.-M., 1998. 3D modelling of seasonal evolution of Loire and Gironde plumes on Biscay Bay Continental Shelf. *In*: 5e Colloque international d'océanographie du golfe de Gascogne, La Rochelle, avril 1996. Oceanol. Acta, 21(2).

Loubersac L., Populus J., Durand C., Prou J., Kerdreux M., Le Moine O., 1997. Système d'information à référence spatiale et gestion d'un espace de production ostréicole : le cas du bassin de Marennes Oléron. Intern. Symp. Bordomer 97, Coastal environment management and protection. October 1997, 2, 186-197.

Populus J., Loubersac L., Prou J., Kerdreux M., Le Moine O., 1997. Geomatics for the management of oyster culture leases and production. *In:* CoastGIS'97, Proc. 2nd Intern. Symp. on GIS and computer mapping for coastal zone management. University of Aberdeen, Scotland, August 1997.

Salomon J.C., 1994. Do not use a simple model when a complex one will do. Comments on a paper by J.C.J. Nihoul. J. Mar. Systems, 5, 401-410.

Salomon J.-C., Breton M., Gueguéniat P, 1995. A 2D long-term advection-dispersion model for the Channel and Southern North Sea. Special issue Mast 52, Part a and b. J. Mar. Systems, 6(5-6), 495-528.

Salomon J.-C., Breton M., 1998. Manuel d'utilisation de Mars 2D. Rapp. Techn. Ifremer, 10 p. + annexes.

Warren I.R., Bach H.K., 1992. Mike 21: a modelling System for estuaries, coastal waters and seas. Environmental software 7. Elsevier Sci. (ed.).

Approche géomatique de l'habitat du grand dauphin en mer d'Iroise

Françoise Gourmelon[(1)], Céline Liret[(2)], Marie Bonnet[(1)]

(1) IUEM, laboratoire Géosystèmes, place Nicolas Copernic, 29280 Plouzané, France
Francoise.Gourmelon@univ-brest.fr

(2) Océanopolis, laboratoire d'étude des mammifères marins, BP 411, 29275 Brest Cedex, France

Résumé

Depuis 1991, un SIG est élaboré au laboratoire Géosystèmes. Il est consacré aux milieux terrestre et marin d'Iroise et fournit des éléments quantitatifs et cartographiques utilisés pour répondre à diverses problématiques de recherche et de gestion. Dans ce cadre et en partenariat avec la mission Parc national marin d'Iroise et le Shom, une application est consacrée aux paramètres environnementaux susceptibles d'intervenir dans la répartition spatio-temporelle des grands dauphins présents en mer d'Iroise. Un test est réalisé sur le groupe côtier observé aux abords de l'île de Sein qui fait l'objet d'un suivi scientifique depuis 1992 (laboratoire d'étude des mammifères marins, Océanopolis). Les répartitions spatiales annuelle et saisonnière des individus révèlent l'existence de secteurs préférentiels au sein de leur domaine vital. La recherche des facteurs responsables de cet apparent déterminisme géographique nécessite la prise en compte de paramètres spatio-temporels qui justifie l'utilisation d'outils géomatiques. Les résultats préliminaires concernant les relations entre les caractéristiques physiques du milieu et la répartition des dauphins aux abords de l'île de Sein sont présentés. La profondeur et la pente semblent influencer le choix du domaine vital, à l'intérieur duquel les sites préférentiels sont caractérisés par la présence de roches émergées. Ces éléments servent de support à la cartographie des sites potentiels au sein de l'aire d'étude. En conclusion, les perspectives envisagées pour modéliser l'habitat du grand dauphin sont présentées et les apports du traitement numérique de l'information géographique aux problématiques environnementales sont discutés.

Abstract

Since 1991, the laboratory Géosystèmes has been involved in developing a multiscale GIS devoted to the study of both marine and terrestrial environments of the Iroise Sea. The GIS produces quantitative and spatial information that are used for either research or management purposes. Within this framework, and in collaboration with three different institutions, the Mission du Parc national marin d'Iroise, Oceanopolis and the Shom, a more specific geographical information database is being

developed. The analysis aims to investigate the environmental factors that may induce the spatio-temporal distribution of the bottlenose dolphins in the Iroise Sea. A local study focuses on a coastal group, observed around the Sein Island, and which has been monitored since 1992 (laboratoire d'étude des mammifères marins, Oceanopolis). The annual and seasonal distributions of this dolphin group reveal some preferential sites inside its vital area. Investigating the factors leading to this perceptible geographical determinism requires that spatio-temporal parameters be considered, and is thus well-suited to GIS analysis. The main objectives of this paper are:

- the presentation of preliminary results on interactions between some physical parameters and the annual distribution of dolphins;
- the discussion of expected results from coupling GIS and an ecological model that describes the relations between dolphins and the other ecosystem components.

These points will provide a basis for discussion concerning both the benefits of numerical processing of geographical information in this sort of environmental study and the appraisal of the interest of this integrated methodology by various partners in the project.

Introduction

Le grand dauphin *(Tursiops truncatus)* fréquente toute l'année l'espace côtier de l'Iroise, petite mer bordière au confluent de la Manche et de l'Atlantique. Espèce emblématique du milieu marin, elle est étudiée depuis la création du laboratoire d'étude des mammifères marins d'Océanopolis en 1990. Les recherches menées ont pour objectifs de déterminer le statut des groupes présents en mer d'Iroise, d'identifier leur domaine vital et leur répartition spatio-temporelle, de caractériser leurs habitats et de définir le degré des interactions avec les activités humaines. Les résultats d'ores et déjà acquis mettent en évidence, d'une part, la présence de deux groupes résidents, l'un de dix-huit individus aux abords de l'île de Sein et l'autre d'une cinquantaine d'animaux dans l'archipel de Molène et, d'autre part, l'existence de secteurs préférentiels au sein de leur domaine vital, variables selon les saisons et l'activité du groupe (Liret *et al.*, 1996). L'hypothèse d'un éventuel déterminisme spatial est de ce fait posée. Elle conduit à réaliser cette étude prospective de l'influence de la topographie des fonds sous-marins sur la répartition géographique du groupe de grands dauphins résidant aux abords de l'île de Sein.
Du point de vue méthodologique, la démarche adoptée est pluridisciplinaire puisqu'elle repose sur des compétences en biologie marine et en géomatique et suit une procédure allant de la collecte des données sur le terrain jusqu'à la restitution cartographique de l'information géographique analysée. Les données environnementales sur lesquelles repose la problématique sont de nature variée et sont récoltées dans une perspective spatiale. Or, elles peuvent gagner en précision géométrique, en cohérence sémantique et en potentialités d'analyse par leur intégration à un SIG (Haines-Young *et al.*, 1993). Sur des problématiques

voisines, des recherches récentes concernant les écotopes de diverses espèces d'oiseaux (Laffly, 1997 ; Tucker *et al.*, 1997), d'insectes (Aspinall & Matthews, 1994) et de mammifères (Vidal, 1993) sont fondées sur des méthodes géomatiques (télédétection et SIG). Toutefois, les applications concernant l'écosystème marin, et plus particulièrement les mammifères marins, restent marginales. À notre connaissance, seuls Moses & Finn (1997) utilisent le couplage d'une base d'information géographique et d'un modèle de régression pour identifier les habitats potentiels de la baleine de Biscaye *(Eubalaena glacialis)* en Atlantique Nord.
Les objectifs de cette étude préliminaire sont :
- de rassembler dans une base d'information géoréférencée l'ensemble des données disponibles sur le milieu marin et sur la répartition géographique du grand dauphin aux abords de l'île de Sein ;
- d'analyser, par des procédures spatiales et statistiques, les relations entre la topographie sous-marine et l'espace utilisé par le grand dauphin ;
- de proposer une cartographie des sites potentiels sur l'aire d'étude.

Matériel et méthodes

Un SIG consacré aux milieux terrestre et marin de la mer d'Iroise s'est mis en place en 1991 à l'université de Bretagne occidentale. Il inclut deux bases d'information géoréférencée, dont l'une est consacrée aux îles et îlots de l'archipel de Molène et à l'île d'Ouessant (Gourmelon *et al.*, 1995) et l'autre à la mer d'Iroise (Le Berre, 1999). Elles sont mises en œuvre dans des problématiques de recherche spécifiques visant à étudier le fonctionnement global et l'évolution de cet espace côtier. L'étude menée sur le grand dauphin constitue à la fois un enrichissement de la base d'information géographique développée sur l'Iroise et une application spécifique.

Zone d'étude

La zone d'étude se situe aux abords immédiats de l'île de Sein (fig. 1). Elle est limitée par l'isobathe des 10 m (de 48°02' N à 48°04' N en latitude et de 4°54'W à 4°48'W en longitude). Cet espace côtier est inclus dans le périmètre du parc naturel régional d'Armorique et est actuellement concerné par le projet de création d'un parc national marin en Iroise.

Constitution de couvertures thématiques

Les données relatives à la répartition spatiale des grands dauphins de l'île de Sein ont été collectées entre 1994 et 1996 selon la méthode de l'échantillonnage instantané (Altman, 1974). Chaque observation est constituée par la position du groupe associée à son activité (prospection alimentaire, repos et déplacement). Ces données sont ensuite reportées sur un quadrillage de la zone d'étude, réalisé à partir de la carte marine du secteur au 1/20 000 (Shom, 1977). Le nombre d'observations par élément de surface, représentant sur le terrain un carré d'environ

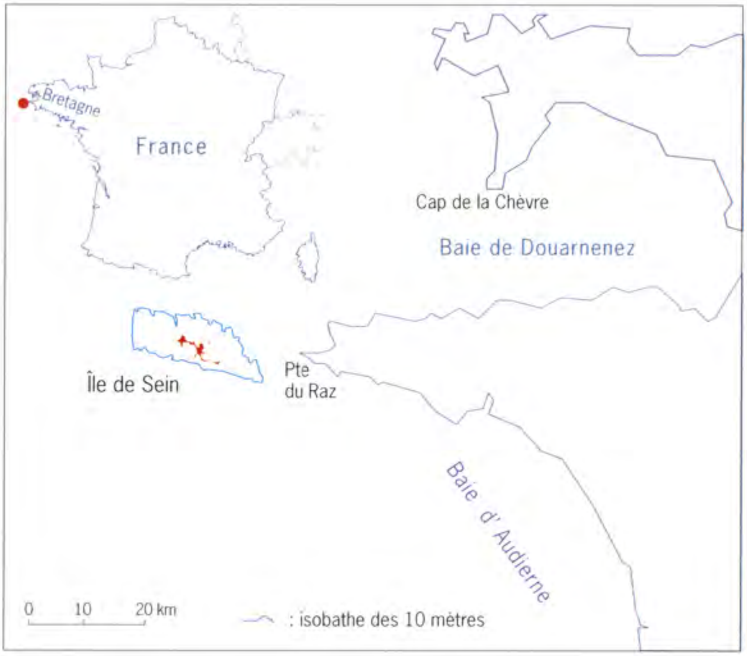


Figure 1
Localisation de l'aire d'étude.

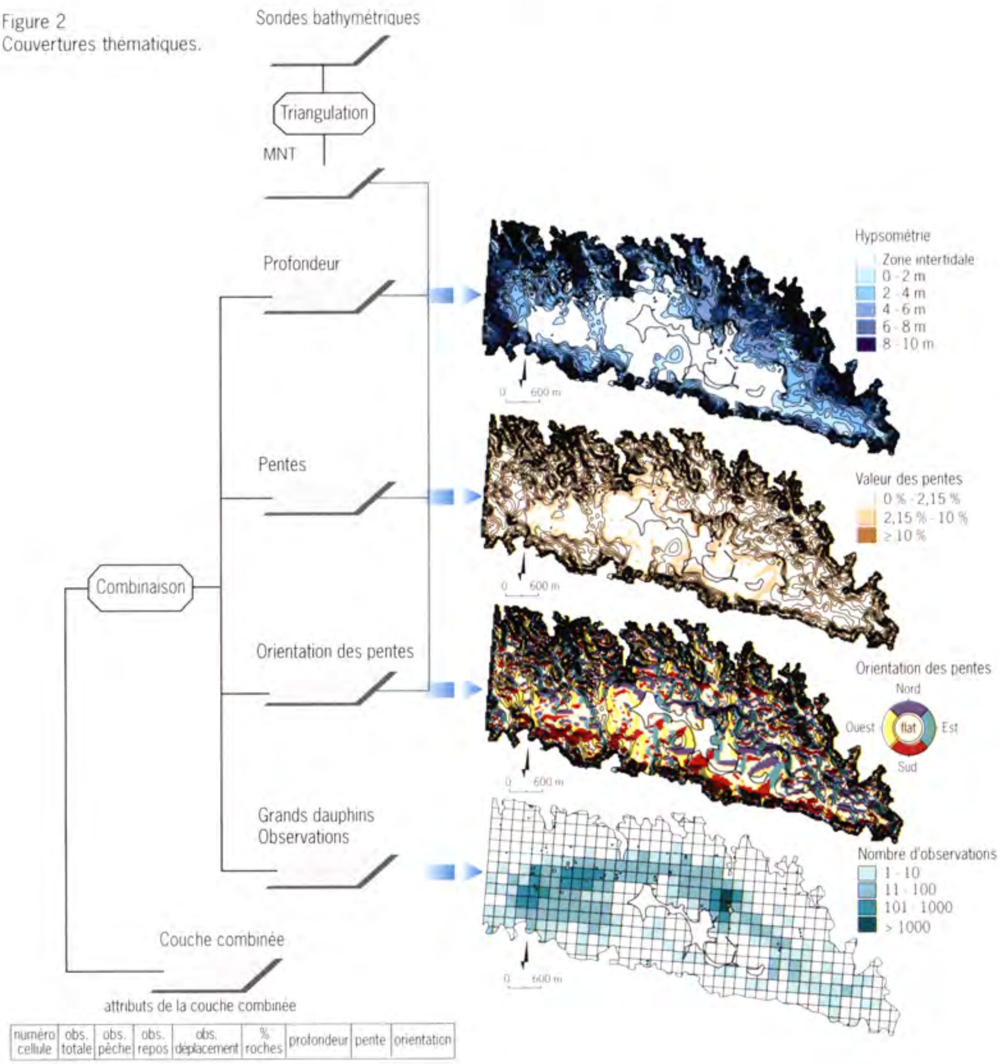
200 m de côté, renseigne ainsi sur son intensité d'utilisation par les dauphins (Liret, 1993). La numérisation des données d'observation est réalisée manuellement en mode vectoriel (fig. 2). Chaque polygone correspondant à un élément du quadrillage d'origine est décrit par les attributs suivants : surface, périmètre, numéro de cellule, nombre d'observations (tous types d'activités, prospection alimentaire, repos, déplacement) et pourcentage de roches émergées. Le référentiel cartographique utilisé est le Lambert II étendu.

L'utilisation des sondes bathymétriques dans le cadre de cette application a fait l'objet d'une convention de mise à disposition de données numériques entre le Shom, Océanopolis et le CNRS. Aux 26 159 sondes disponibles sur la zone d'étude sont associées les coordonnées géographiques, la profondeur (précision décimétrique) et la date d'acquisition. Les sondes sont stockées dans une couverture d'entités ponctuelles qui fait l'objet d'une projection cartographique en Lambert II (fig. 2). Elles permettent de réaliser un modèle numérique de terrain (triangulation de Delaunay : Tin), qui est ensuite utilisé pour décrire la topographie des fonds sous-marins. La profondeur est traitée en six classes (estran, 0-2 m, 2-4 m, 4-6 m, 6-8 m et 8-10 m). La pente, calculée en pourcentage, est exprimée par trois intervalles (0-2,15 %, 2,15-10 % et supérieure à 10 %) et son orientation est définie par quatre directions principales (est : 45°-135°, sud : 135°-225°, ouest : 225°-315° et nord : 315°-45°), auxquelles s'ajoute une classe d'orientation quelconque pour les surfaces planes. Ces trois variables topographiques ne sont pas calculées pour les îles et îlots.

Analyses

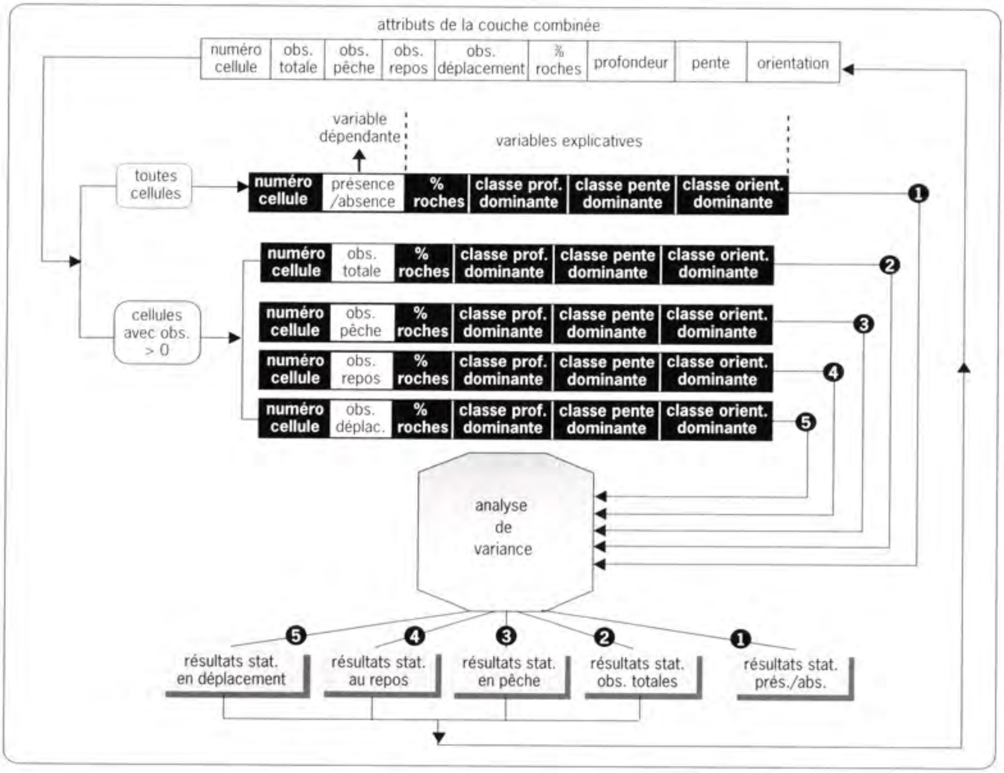
La première étape de l'analyse repose sur la mise en œuvre d'une opération strictement géométrique proposée par la « boîte à outils » du SIG (fig. 2). Elle fait partie d'une famille de requêtes ou algèbre de cartes (Rimbert, 1992) qui constitue le premier niveau de l'analyse spatiale. La procédure suivie a pour objectif de produire une couche d'information inédite par combinaison des quatre couvertures thématiques initiales (observations des dauphins, profondeur, pente, orientation des pentes). Il en résulte une couverture polygonale dont les 13 000 objets sont décrits par l'ensemble des attributs thématiques des quatre couvertures de base auxquels s'ajoutent les attributs de surface et de périmètre recalculés sur la couverture finale.

Figure 2
Couvertures thématiques.



La seconde étape de la procédure consiste à extraire du SIG le tableau de données associé à ce plan d'information pour le soumettre à une analyse statistique, de type « analyse de variance » (fig. 3). Les variables dépendantes correspondent aux observations de grands dauphins, toutes activités confondues ou par activité. Chacune d'entre elles est analysée en fonction des variables explicatives décrivant les paramètres topographiques de l'aire d'étude. Différentes procédures du logiciel SAS sont utilisées afin de mettre en évidence les paramètres intervenant sur la répartition spatiale du grand dauphin de l'île de Sein selon deux approches : sur l'ensemble de la zone d'étude d'une part et, d'autre part, sur l'espace utilisé par les grands dauphins, qualifié de domaine vital.
Dans une troisième étape, les résultats de l'analyse statistique sont réintroduits dans la base d'information géographique. Quatre nouveaux attributs décrivant les potentialités du milieu sont ajoutés à la couverture combinée. Par un jeu de requêtes, les objets répondant aux critères significatifs révélés par l'analyse statistique sont identifiés. Une nouvelle couverture décrivant les potentialités de l'aire d'étude pour le groupe de dauphins est produite.

Figure 3
Traitements statistiques.



Résultats

Les résultats acquis concernent les paramètres topographiques de l'aire d'étude intervenant, d'une part, sur le choix du domaine vital des grands dauphins et, d'autre part, sur la répartition spatiale du groupe au sein de cet espace. Ils conduisent à réaliser la cartographie des sites potentiels aux abords de l'île de Sein.

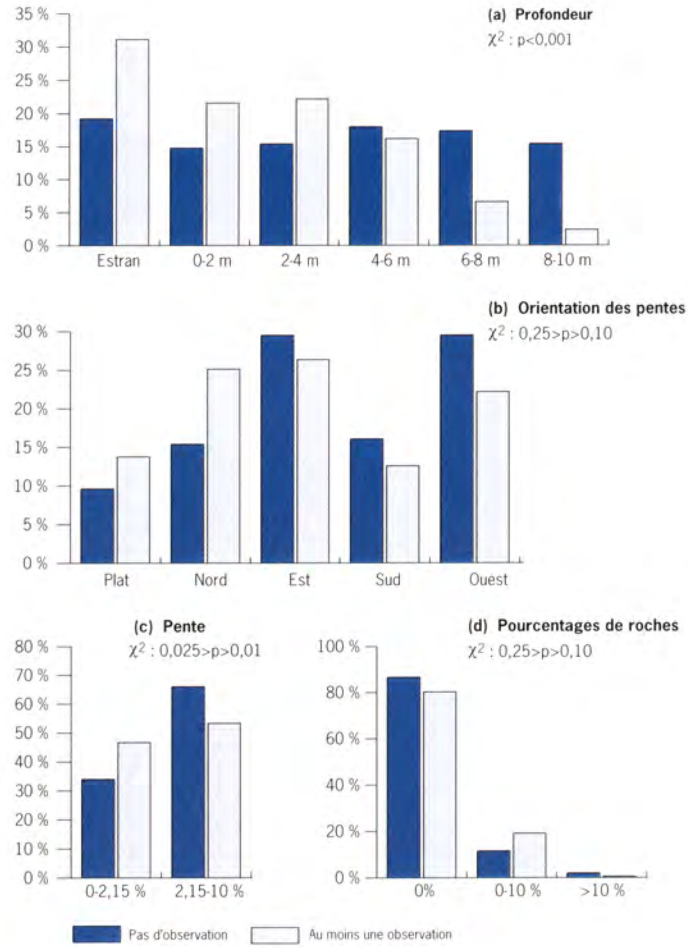
Caractéristiques de la zone d'étude

L'aire d'étude, limitée par l'isobathe des 10 m, s'étend sur environ 13 km^2 autour de l'île de Sein. Au cours des deux années d'observation, le groupe de grands dauphins a utilisé 52 % de cette surface. Les composantes environnementales de l'espace où les animaux ont été observés au moins une fois sont comparées à celles du reste de la zone d'étude, comportant uniquement des cellules sans observation (fig. 3). Cette première étape de l'analyse, plutôt descriptive, a pour objectif de mettre en évidence les paramètres topographiques de l'ensemble de la zone intervenant sur le choix du domaine vital des dauphins.
Parmi les variables topographiques testées, les valeurs de χ^2 indiquent que seules la profondeur et la pente présentent une différence significative ($p<0.05$) entre l'espace avec observation de dauphins et celui sans (fig. 4). Les différentes classes de profondeur sont approximativement équivalentes hors de la surface exploitée par le groupe ; par contre, les dauphins utilisent préférentiellement un espace extrêmement côtier allant de l'estran à 6 m de profondeur (fig. 4a). En ce qui concerne la pente, les proportions des deux classes sont presque identiques au sein du domaine vital des dauphins par rapport au reste de la zone d'étude où une inclinaison comprise entre 2,15 % et 10 % est représentée majoritairement (fig. 4c). Les deux autres variables environnementales prises en compte, l'orientation des pentes et le pourcentage de roches émergées, présentent des distributions équivalentes pour les surfaces avec et sans observation du groupe, d'où une valeur de χ^2 supérieure à 0,05 (fig. 4b-d). Ces deux paramètres montrent que le domaine vital des dauphins s'étend plus particulièrement sur des fonds sous-marins caractérisés par des pentes orientées au Nord, à l'Est et à l'Ouest et où la roche émergée est absente, éléments prépondérants sur l'ensemble de la zone d'étude.

Domaine vital

L'analyse statistique est ensuite réalisée sur les éléments de surface comprenant au moins une observation du groupe de grands dauphins (fig. 3). L'intensité d'utilisation de chaque entité est prise en compte, toutes activités confondues et pour chaque activité. Cette seconde étape a pour but de rechercher les paramètres intervenant sur la répartition spatiale du groupe au sein du domaine vital ; ils impliquent une utilisation préférentielle de certains sites.

Figure 4
Résultats statistiques concernant le choix du domaine vital.



L'analyse de variance effectuée prend en compte les trois variables topographiques et le pourcentage de roches émergées ; elle permet dans un même temps d'analyser les interactions potentielles entre la profondeur, l'orientation et le degré de pente. Les résultats obtenus indiquent clairement que, quelle que soit la variable dépendante (intensité d'observation des dauphins), le pourcentage de roches dans la maille d'observation intervient sur la distribution des animaux au sein de leur territoire (fig. 5). Pour l'activité de repos, la valeur de la pente intervient également sur le choix des sites, les animaux utilisant préférentiellement des secteurs dont la pente est supérieure à 10 %. En ce qui concerne le déplacement, les zones utilisées présentent des plages de profondeur comprises respectivement entre 2 et 4 m et 8 et 10 mètres. Par contre, aucune interaction entre les trois variables topographiques ne fournit de résultats significatifs.

Figure 5
Résultats des analyses de variance concernant le domaine vital.

Variables explicatives	Variables dépendantes : Ensemble des activités	Prospection alimentaire	Repos	Déplacement
Profondeur (BA)	*NS*	*NS*	*NS*	**0,0257** 2-4 m , 8-10 m
Pente (DG)	*NS*	*NS*	**0,0053** >10 %	*NS*
Orientation des pentes (OR)	*NS*	*NS*	*NS*	*NS*
% de roches émergées	**0,0001**	**0,0007**	**0,0110**	**0,0123**
BA • OR	*NS*	*NS*	*NS*	*NS*
BA • DG	*NS*	*NS*	*NS*	*NS*
DG • OR	*NS*	*NS*	*NS*	*NS*
BA • DG • OR	*NS*	*NS*	*NS*	*NS*

NS : variable non significative (p > 0,05)

Sites potentiels

La réintroduction de ces variables topographiques significatives dans la base d'information géographique permet d'identifier les secteurs de la zone d'étude possédant les caractéristiques en partie à l'origine de la répartition spatiale des dauphins, pour toutes activités confondues ou pour chaque comportement. Ces espaces, inclus dans la zone d'étude, peuvent être qualifiés de sites potentiels pour le groupe de l'île de Sein (fig. 6). Parmi les secteurs identifiés, aux zones préférentielles mises en évidence lors du suivi des animaux s'ajoutent des micro-espaces au sein desquels aucune observation n'a été réalisée à ce jour.

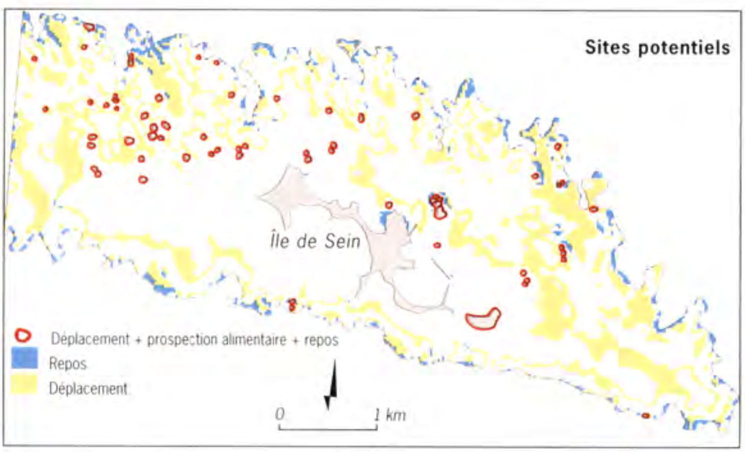


Figure 6
Localisation des sites potentiels aux abords de l'île de Sein.

Discussion

Ces résultats préliminaires indiquent que la répartition spatiale des grands dauphins semble être en partie dictée par les variables topographiques des fonds sous-marins. Parmi les quatre variables testées, la profondeur et la pente semblent être des paramètres influençant le choix du domaine vital. Au sein de cet espace, le groupe fréquente préférentiellement certains sites caractérisés par la présence de roches émergées. Selon leur activité, ils tiennent également compte de la profondeur (cas du déplacement) ou de l'inclinaison de la pente (cas du repos). D'autres études menées sur des groupes de grands dauphins côtiers ont montré que les animaux étaient concentrés dans des secteurs caractérisés en partie par la profondeur (Berrow *et al.*, 1996; Wilson *et al.*, 1997). En ce qui concerne la pente, les travaux réalisés sur des dauphins de Risso dans le golfe de Mexico indiquent qu'il existe une relation directe entre la présence des animaux et cette variable (Baumgartner, 1997). Par contre, l'ensemble des études menées sur les cétacés, et en particulier sur les grands dauphins en milieu côtier, met en évidence l'intervention du courant sur la répartition spatiale des animaux. Ce paramètre semble être déterminant pour l'activité de prospection alimentaire; il serait donc nécessaire de le prendre en compte, avec d'autres facteurs environnementaux, pour comprendre le déterminisme spatial de ces mammifères marins au sein de leur domaine vital.
En conséquence, il est indispensable d'élargir à d'autres variables environnementales l'analyse spatiale réalisée dans cette étude, ce qui implique de coupler le SIG à la modélisation. En premier lieu, la modélisation hydrodynamique permettrait la production d'informations spatiales et temporelles telles que les modes hydrodynamiques et les courants. La modélisation écologique produirait, en complément des mesures acquises, une information spatio-temporelle sur les composantes des écosystèmes pélagique et benthique. L'ensemble des résultats issus de la modélisation serait intégré dans la base d'information géographique, sous forme de couvertures thématiques, et compléterait le jeu de données.
Du point de vue méthodologique, à ce stade de la recherche, le SIG permet le stockage, la gestion et l'analyse de données géoréférencées de nature variée. Il offre ainsi la possibilité de mettre en cohérence spatiale et sémantique des données acquises sur différents types de support (analogique et numérique), dans des systèmes de projection cartographique divers et selon des modes de représentation des objets géographiques multiples. De plus, le couplage de ces systèmes avec les logiciels spécialisés dans l'analyse statistique offre des atouts pour décrire qualitativement et quantitativement les relations entre plusieurs variables environnementales.

Conclusion

Si les résultats présentés ne constituent qu'une approche limitée de l'habitat du grand dauphin en mer d'Iroise, ils confirment néanmoins l'existence de secteurs privilégiés au sein de leur domaine vital, caractérisés par la présence d'îlots et par une topographie sous-marine particulière.

Ils justifient d'intégrer à l'analyse, dans un développement futur, une dimension temporelle (répartition des dauphins à l'échelle de la journée, du mois, de l'année...) et d'élargir les paramètres environnementaux à la prise en compte de la nature du substrat, du taux de couverture algale, des modes hydrodynamiques, des courants de marée et des activités anthropiques. L'intégration de ces multiples paramètres environnementaux devrait permettre la caractérisation de l'habitat du grand dauphin et sa modélisation à l'ensemble de la mer d'Iroise. Cette information constitue un élément essentiel pour une gestion durable de la diversité marine au sein du parc national marin en cours de création.

La démarche fédératrice proposée par les SIG est un atout dans ce type de recherche pluridisciplinaire. Leur environnement intégrateur fournit en effet un support de réflexion, d'échanges et de connaissances fort enrichissant. La démarche commune conduit à expliciter les choix méthodologiques en termes de production et d'analyse de l'information spatiale : élaboration des typologies, choix des échelles et des supports d'observation, nature des objets géographiques manipulés dans les différents thèmes, modes de structuration et de représentation de l'information géographique numérique. Cette expérience confirme que les SIG sont des outils d'échange et de communication au service de la connaissance d'un processus environnemental autant que d'un territoire.

Références bibliographiques

Altman J., 1974. Observational study of behaviour: sampling methods. Behaviour 49(3-4), 227-267.

Aspinall R., Matthews K., 1994. Climate change impact on distribution and abundance of wildlife species: an analytical approach using GIS. Environ. Pollut., 86, 217-223.

Baumgartner M.F., 1997. The distribution of Risso's dolphin *(Grampus griseus)* with respect to the physiography of the northern gulf of Mexico. Mar. Mamm. Sci., 13(4), 614-638.

Berrow S.D., Holmes B., Kiely O.R., 1996. Distribution and abundance of bottle nose dolphins *Tursiops truncatus* in the Shannon estuary. Biology and environment. Proc. Royal Irish Acad., 96B(1), 1-9.

Gourmelon F., Bioret F., Brigand L., Cuq F., Hily C., Jean F., Le Berre I., Le Démézet M., 1995. Atlas de la réserve de biosphère de la mer d'Iroise : exploitation cartographique de la base d'information géographique Sigouessant. Cah. Sci. Parc Nat. Rég. Armorique, 96 p.

Haines-Young R., Green D.R., Cousins S.H., 1993. Landscape ecology and GIS. Taylor & Francis (eds), 288 p.

Laffly D., 1997. Écologie, télédétection et SIG. : les écotopes du grand tétras dans le Haut-Jura. Mappemonde, 3, 27-30.

Le Berre I., 1999. Mise au point de méthodes d'analyse et de représentation des interactions complexes en milieu littoral. Doctorat de l'université de Bretagne occidentale, Brest, 230 p.

Liret C., 1993. Aspects de l'écologie alimentaire du grand dauphin, *Tursiops truncatus*, autour de l'île de Sein. Rapport de DEA, océanologie biologique, université de Bretagne occidentale, Brest.

Liret C., Creton P., Ridoux V., 1996. Seasonal variations in habitat use and activity budget by resident bottlenose dolphins at île de Sein, France. Eur. Res. Cetaceans, 9, 146-149.

Moses E., Finn J.T., 1997. Using geographic information systems to predict North Atlantic right Whale *(Eubalanea glacialis)* habitat. J. Northw. Atl. Fish. Sci., 22, 37-46.

Rimbert S., 1992. Données pour une algèbre de cartes. Bull. Soc. Fr. Photogr. Télédétec., 125, 14-25.

Shom, 1977. Carte marine océan atlantique, côte ouest de France : Raz de Sein, 5252, fév. 1977.

Tucker K., Rushton S.P., Sanderson R.A., Martin E.B., Blaiklock J., 1997. Modelling bird distributions, a combined GIS and bayesian rule-based approach. Landscape Ecol., 12(2), 77-93.

Vidal F., 1993. Traitement d'image de télédétection et SIG pour l'étude du comportement des chevreuils. Mappemonde, 4, 26-27.

Wilson B., Thompson P.M., Hammond P.S., 1997. Habitat use by bottlenose dolphins: seasonal distribution and stratified movement patterns in the moray firth, Scotland. J. Appl. Ecol. 34, 1365-1374.

Remerciements

Les auteurs remercient vivement Emmanuel Giraudet (cartographe, Géosystèmes UMR 6554 CNRS).

The development of a GIS-based system for Integrated Coastal Zone Management (ICZM)

A.P. Jones[(1)], T. Thumerer[(1)], M. Guthrie[(1)], T. Crowards[(1)], D. Brown[(2)], R.K. Turner[(1)]

(1) University of East Anglia, School of Environmental Sciences, Centre for Social and Economic Research on the Global Environment (CSERGE), Norwich, Norfolk, NR4 7TJ, UK
a.p.jones@uea.ac.uk

(2) University of East Anglia, School of Environmental Sciences, Applied Environmental Management Unit, Norwich, Norfolk, NR4 7TJ, UK

Abstract

There is an expanding interest in the use of GIS as a decision support tool in integrated coastal zone management (ICZM) programmes. On the face of it, GIS certainly appear to be attractive tools to facilitate the execution of ICZM activities. However, whilst the findings of GIS based research may potentially be of both academic and practical interest, they will be of little significance to coastal managers and planners if they cannot easily obtain access to them. To illustrate how this might be facilitated, the incorporation of ICZM principles into easy to use GIS based decision support systems is outlined using two case studies, one of an illustrative coastal zone known as Prospero Bay, and the other for the real-world coastline of Eastern England.

Résumé

L'utilisation de SIG comme outils de support de décision dans des programmes de gestion intégrée de zones côtières (GIZC) suscite un intérêt grandissant. À première vue, les SIG semblent être des outils attrayants pour faciliter l'accomplissement d'activités GIZC. Cependant, bien que les résultats de recherche basés sur des SIG soient d'intérêt à la fois théorique et pratique, les SIG ne pourront être utilisés par les responsables et les planificateurs que si ces derniers peuvent y accéder. Pour illustrer comment ceci pourrait être facilité, l'incorporation de principes de GIZC dans des systèmes de support de décision basés sur des SIG est démontrée en utilisant deux études de cas, l'un sur la zone côtière imaginaire appelée Prospero Bay, l'autre sur la côte réelle de l'est de l'Angleterre.

Introduction

The coast is highly valued by society for the market and non-market goods and services it provides (Turner *et al.*, 1998). However, the potential for coastal developments to have wide ranging and often indirect impacts is increasingly recognized, and even development work with clearly recognized local objectives may have adverse effects elsewhere along the coast. These conflicts, coupled with an escalating demand for coastal resources, the restricted geographical extent of the coastal zone, and the fragile nature of many coastal environments means that the shoreline is an area that requires careful management. It is important that successful coastal management strategies are supported by the implementation of rational, integrated, and sustainable interventions that are centred around the principles of long-term planning (Bartlett, 1994). The term Integrated Coastal Zone Management (ICZM) is nowadays often used to address this type of process (Bower & Turner, 1998). Whilst there are many potential benefits to adopting an integrated approach, ICZM requires that environmental managers and planners have access to a diverse range of high quality spatially referenced data on the physical, biological, and socio-economic processes operating within the zone (Lucas, 1996). Hence, it is unsurprising that there is a growing interest in the development of coastal zone information systems based on GIS technologies (Bartlett, 1994).

An early attempt at a basic decision support system for coastal management in South Africa was outlined by Raal *et al.* (1995). Recently, more sophisticated systems have been developed. A particularly impressive example is the Rapid Assessment Module for Coastal zone management (RaMCo), produced by de-Kok *et al.* (1997). Centred on the coastal zone of South-West Sulawesi, Indonesia, RaMCo combines a basic GIS with a dynamic system model for biophysical and socio-economic coastal zone interactions.

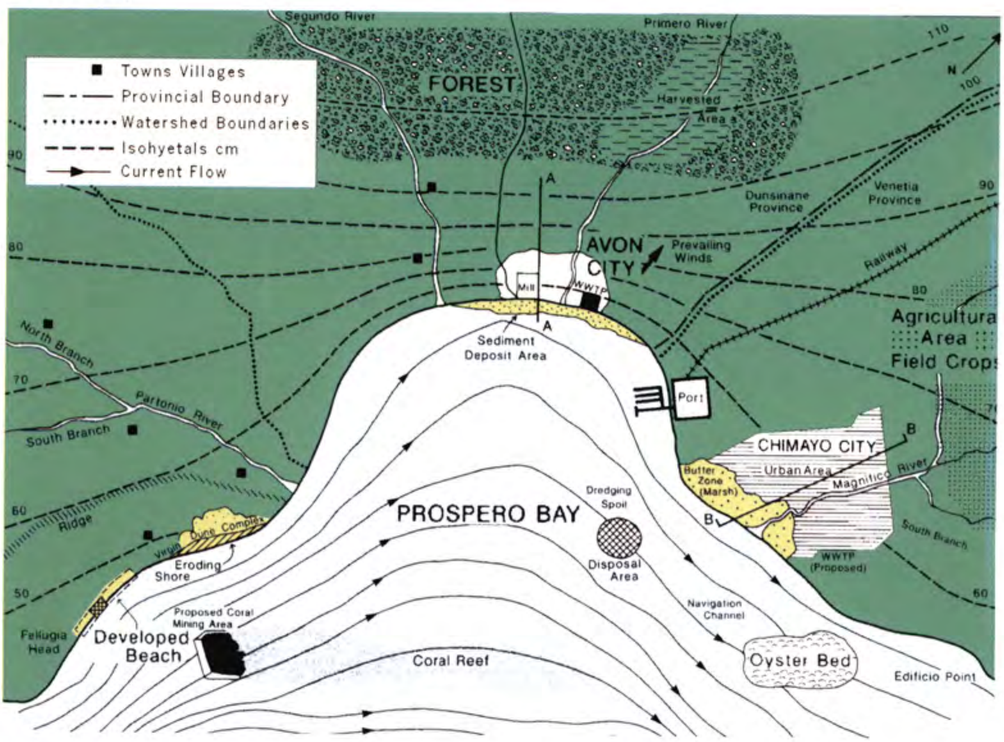
On the face of it, GIS certainly appear to be attractive tools to facilitate the execution of ICZM related programmes. Their ability to accommodate and integrate large databases means that they may play an important role in the decision making process. These attributes, coupled with their provision of advanced mapping and spatial analysis facilities, are reasons why they are increasingly being implemented by those charged with the task of administering stretches of coast (Bartlett *et al.*, 1997). However, whilst the use of the technology as a tool for land-based resource management and planning is well established, GIS applications in coastal and aquatic environments are often rather poorly defined (Ricketts, 1992). At least in part, this may be due to the fact that off-the-shelf GIS are generally lacking the basic functionality required to tackle many coastal management issues (Maslen *et al.*, 1996). These limitations are compounded by the fact that coastal decision-makers are often overwhelmed by the complexity of many GIS applications (Green, 1995; Raal *et al.*, 1995). Consequently, much of the potential of the technology remains unrealised.

At present the theory of ICZM is well defined, but its practical application is much less developed. At the UK Centre for Social and Economic Research on the Global Environment (CSERGE), research is being undertaken with specific aims of applying the theory and rhetoric of ICZM to practical applications. The work recognizes that any system constructed to aid the implementation of ICZM policies should be based on high quality science, yet must also be able to be easily used by non-technical experts, coastal managers, and policy makers. Hence, the research centres around the production of an easy to use ICZM modelling application coupled with a GIS database holding information on the coastal environment. An evolutionary approach has been taken. This initially entailed the construction of a prototype coastal management system for Prospero Bay, an imaginary coastal zone containing a diverse range of resources and associated resource conflicts. Based on the success of this prototype, work is currently ongoing to construct a fully GIS-based model for the real-world coastline of the region of East Anglia, England. This chapter details the development of this research.

Prospero Bay

Prospero Bay is a prototype region with characteristics similar to those of real-world coastal areas. It is designed to provide a realistic context for demonstrating the advantages of integrated management over the single issue approach. Although somewhat simplified, the prototype

Figure 1
The geography of Prospero Bay.



is sufficiently complex to allow for comparison of trade-offs among outputs, as in the real-world. The geography of Prospero Bay is shown in figure 1.

Running along the mouth of the bay is a relatively pristine coral reef and a commercially exploited oyster bed. A residual surface current flows into the bay from the south between the coral reef and Fellugia Head. Four watersheds discharge into the ocean. A dune system has developed seaward of a ridge running from west of Fellugia Head to just south of the Partonio river mouth. Shallow waters in the north of the bay provide spawning grounds for anadromous fish, sustaining a local fishery. Avon city lies on the north coast, just below a large forest. From the high land of the forest, the topography slopes downwards to the alluvial plain of the Magnifico river. A marsh lies to the south of the river and inland, bordering the marsh, is the city of Chimayo. Above the floodplain is a fertile plateau dominated by agricultural crops. The major centres of population are the cities of Chimayo and Avon. Elsewhere, the zone is sparsely populated. Industry is located within the cities, with an integrated paper mill and numerous electroplating activities in Avon. Chimayo is a major international port, and there are sand mining operations on the coast between the Partonio and Segundo rivers as well as logging activities in the forest to service a paper mill. Tourism is confined to the marsh and dune area.

Within the bay there are demands for multiple products and services, with each resource being subject to very different, but interrelated, conflicts. For example, the effects of erosion from the sand and dune mining operation are leading to a build up of coarse sediment on the beach at Avon City. The beach is unsuitable for recreation, yet serves a role in flood defence. Hence, increases in the volume of the beach will reduce the maintenance costs of the sea wall protecting the city. However, although there is a net increase in the amount of sediment forming the beach, it is also undergoing some erosion with sediment moving out into the bay. This has a particularly adverse impact upon spawning in the fisheries.

The Prospero Bay model has been developed with the input of scientists from a range of disciplines. The rationale for the model is that underlying science should be as realistic as possible, whilst ensuring ease of use for policy makers. Both the front-end and the ICZM modelling modules are written in Microsoft Visual Basic, and are designed around a multiple-windows environment. The users are initially presented with an introduction screen that allows them to obtain an overview of the rationale behind the system, or more detailed information on the resources and conflicts within the Bay (fig. 2). Low, medium, and high economic growth scenarios can also be specified from here, and the planning horizon may be set for any period up to ten years. Each resource within Prospero Bay has its own resource allocation screen whereby the user may review the current characteristics of the resource, and alter those that are variable so as to test the impacts of different management scenarios.

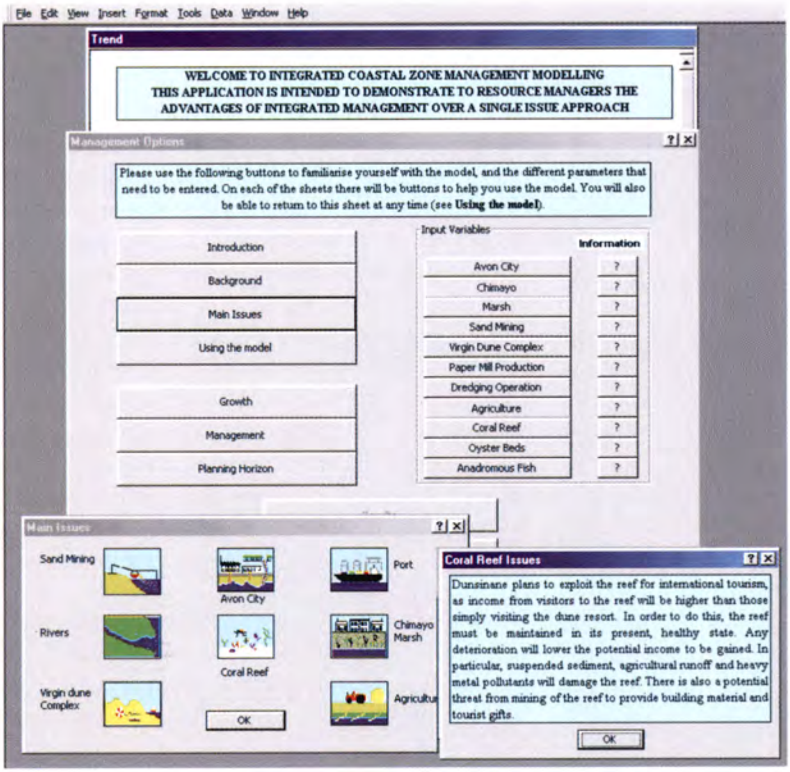


Figure 2
The Prospero Bay model utilises an easy-to-use windows-based front-end.

When the basic input and assumptions for each scenario have been specified, the user is able to run the ICZM model and obtain a tabular output that predicts the state of the bay at the end of the planning horizon. So as to provide a common output unit, the principles of environmental economics are applied to the model outcomes, and the costs and benefits of the scenario run are given in monetary terms. The use of an economic approach is controversial. However, the aggregate impact of any ICZM related project is both context and spatially specific. An extended cost-benefit approach, such as that incorporated into Prospero Bay, has the potential for a standardised, heuristics aid to the policy process, providing that its central economic welfare assumptions are clearly visible (Turner, 1997). Where they are not, the danger of regulatory or institutional capture is increased.

The Prospero Bay application works on a pseudo-geography where the entities within the Bay are not simply specified by their relative spatial locations, but also by their interactions with each other. Hence it employs a complex network of transfer coefficients, determined by the results of known analytical processes, that in turn predict the effects of the current environmental state of the Bay on each resource. In this respect, the model completes a number of iterations until the end of the planning horizon is reached.

Prospero Bay illustrates the considerable potential of modelling applications to aid the implementation of complex ICZM strategies. However, as the Bay is imaginary, it is not in itself of practical value for real-world decision making. The required logical step is to transfer the principles, expertise, and knowledge gained from the development of Prospero Bay to a real-world coastal environment. Researchers in CSERGE are currently developing a fully GIS based ICZM modelling package to act as a decision support system for management of the coastline of the East Anglian Region, England.

The East Anglian Coastal Management System

With a length of 1 240 km, the East Anglian coastline runs from the Thames to the Humber estuaries. The coast is one of the most outstanding areas for wildlife and natural features in England. Its range of geomorphologic features, in particular the sand and shingle formations, its saltmarshes and associated plant communities, and its breeding and wintering bird populations are unparalleled and of international importance (Millar, 1997).

This length of the coast is at particular risk of inundation by the sea; most of the land is low-lying and is especially vulnerable to storm surges as water is channelled from the North Sea through the narrow English Channel. Parts of the east coast are also suffering from serious erosion, and many sea defences built after significant flooding in 1953 are becoming increasingly exposed. Unsurprisingly, there is a long history of coastal flooding combated by sea defences dating back through the Middle Ages to Roman times (MAFF, 1996). Medieval maps show relative distributions of land and water differing significantly from the present situation, and the coastal lowlands within the study area have been subjected to a number of major flood incidents resulting in considerable loss of life and property.

The vulnerability of the east coast means that careful management of the shoreline is particularly important (Brown *et al.*, 1994). At present, management practices in the United Kingdom (UK) are governed by the Shoreline Management Plans (SMPs) (MAFF, 1998; Diment, 1994). The smallest spatial unit delineated by each SMP is the management unit (MU). These are areas of the coast within which relatively homogeneous sedimentation processes operate, and they form the basic compartments within which management regimes are operative. The study area contains approximately 140 units. The maintenance of sea defences within each unit is central to the SMP. However, improving or maintaining all sea walls in their current condition is not a viable policy option. Conventional sea walls are extremely expensive, costing on average more than £1000 per metre. Their construction or strengthening can also cause damage elsewhere along the coast by restricting the supply of sediment (Pearce, 1996). Because of these limitations, it is vital that long term planning efforts and resources for the eastern coastal zone are specifically targeted at areas that will be most vulnerable to flooding in the future.

Its location and low lying nature means the coast of East Anglia is vulnerable to the effects of global warming. Because of this vulnerability, the climate change associated aspect of coastal management was chosen for the initial development of the GIS Management System. Of course, the use of GIS for the assessment of coastal flooding is not new (Shennan, 1993; Zeidler, 1997) but previous work has often not fully exploited the technology. The methodology adopted for this application is outlined below.

Modelling flood risk along the east coast

The first stage in the research centred around the construction of a GIS based risk assessment model. Vulnerability was modelled as being a function of three main coastal processes; tidal and storm surge activities, sea-level rise, and isostatic adjustment.

To estimate the impacts of storm surges, information was provided by the Proudman Oceanographic Laboratory on high water predictions for a period of up to 10 000 years at various locations along the coast (Dixon & Tawn, 1997). A prediction of high water return periods for each management unit was then calculated in Arc/Info using interpolation; values for each unit were estimated as a function of the return periods for the nearest two adjacent data points and the distance from those points to the mid-point of the unit.

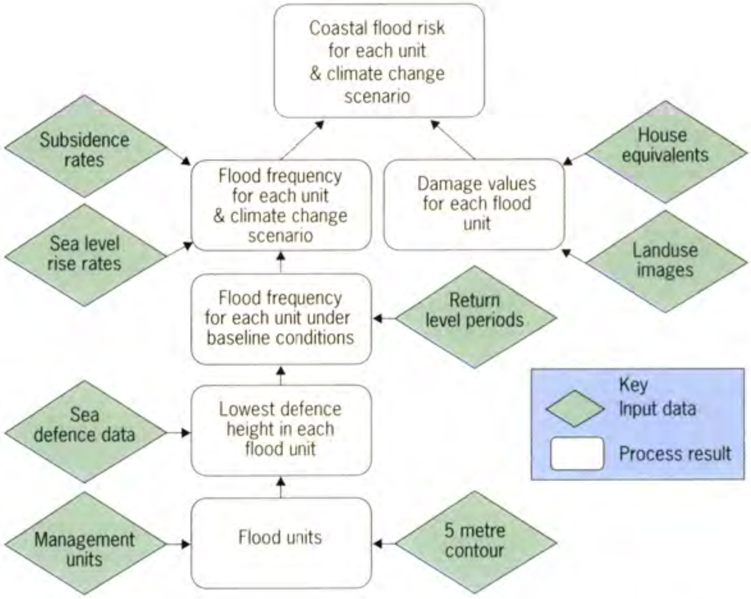
Sea level rise predictions were made using the results of research by the Climatic Research Unit of the University of East Anglia. Values for projected sea level rise under different climate change scenarios were derived from the Model for the Assessment of Greenhouse-gas Induced Climate Change (MAGICC) (Hulme *et al.*, 1995). Based on the output of MAGICC, the estimated sea level (relative to the base year 1990) was derived for all years up to 2100. For each management unit, the sea level rise estimates associated with three different model scenarios (corresponding to a mean warming of 1.5°C, 2.5°C, and 4.5°C respectively) was computed.

A final important consideration was the impact of isostatic uplift, *i.e.* the movement of the land level since the last glaciation that is causing the subsidence of most of southern England. This has obvious implications for determining vulnerability of the coast to sea level rise. Estimates of yearly mean isostatic adjustment rates for each management unit were derived in Arc/Info based on a interpolation of point predictions made for eastern England by Shennan (1989).

The basic spatial units chosen for analysis were MUs. The steps developed to assess climate-change associated flooding risk for each MU are outlined in figure 3. Because MUs do not have an official designated landward extent, the 5 m elevation contour was used. In cases where the 5 km contour lay more than 5 km from the coast, a 5 km buffer zone was used to close the MU instead.

A major task involved quantifying the level of flood protection provided within each management unit. For this purpose, data on sea defence heights and backshore elevation values was taken from the National Sea

Figure 3
The stages adopted during the development of the flood hazard model.



Defence Survey (SDS) held by the UK Environment Agency. The SDS is based on fieldwork undertaken by Sir William Halcrow and Partners in 1990. It forms part of the Shoreline Management System which is the Environment Agency coastal GIS database (Leggett & Jones, 1996). The SDS is constructed using the Intergraph GIS and Oracle database packages, but was converted into Arc/Info format for this analysis. Arc/Info was used to query SDS to determine the lowest defence height in each management unit. Flood hazard was then modelled as a function of two mechanisms: overtopping and structural defence failure (Meadowcroft *et al.*, 1996). In order to derive the annual frequency of an overtopping event under baseline conditions (year 1990), the return level frequencies for extreme water heights were compared with the corresponding lowest defence heights in each flood unit. It was assumed that if a given water level exceeded the lowest defence height, the whole unit would be flooded.

Integration of the model into a coastal management system

To incorporate the output of the hazard analysis into a Prospero Bay like modelling application, a decision support system has been developed that consists of a simple front-end and a coastal process modelling application, both written in Visual Basic. These are close coupled to a mapping applet, Microsoft Datamap, produced by the Mapinfo Corporation. The package is structured in such a way so as to provide coastal managers, the anticipated users, with a link between potentially useful GIS technology and data and understanding of the processes operating within the coastal zone. Significantly, it has been designed for users with little or no GIS experience, and it can run on almost any PC equipped with Microsoft Windows.

The system combines the coastal flood risk models with information on projected population growth for each management unit derived from UK census of population statistics (Openshaw, 1995). At present it allows users to estimate flood risks in each management unit for any year up to 2100 based on the Intergovernmental Panel on Climate Change (IPCC) sea level risk predictions (Houghton *et al.*, 1996). The user is able to incorporate population growth predictions, and then estimate the population at risk (in terms of both households and persons) from flooding at any point in the future. Cartographic output is provided in the form of predicted risk and population maps for management units. The maps are dynamic, and automatically update when the assumptions of the scenarios change. Statistical functionality is provided in the form of tables and three dimensional charts.
The use of the system to estimate the population at risk in the year 2050 under IPCC sea level rise hazard scenario A (corresponding to a mean sea level rise of 19.77 cm by 2050 and 48.87 by 2100) is illustrated.

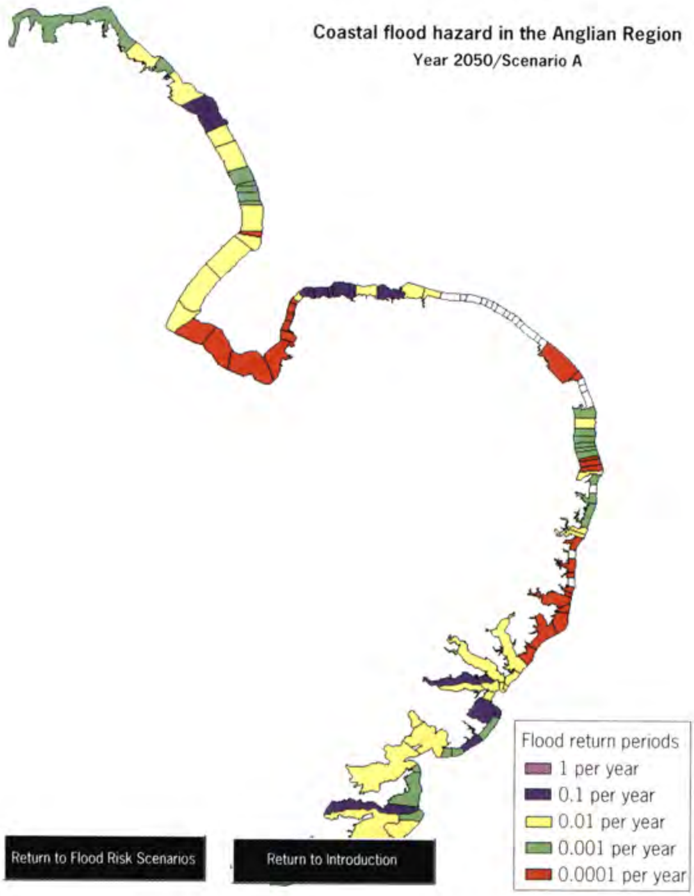
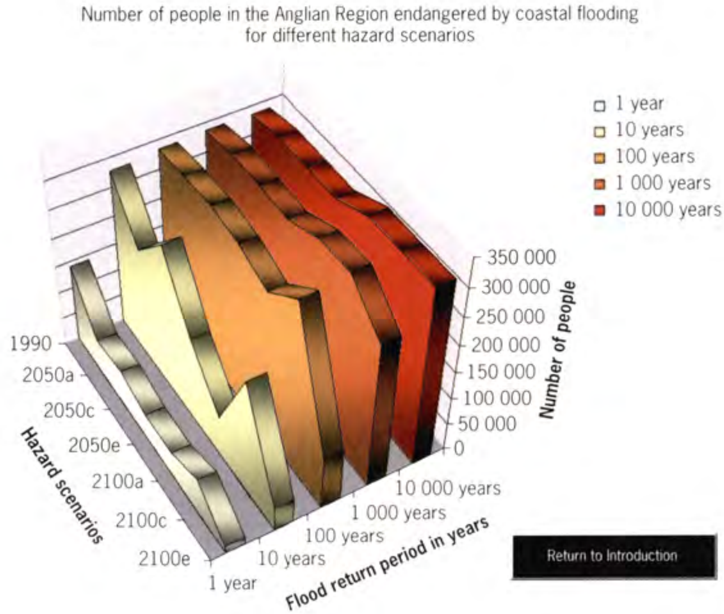


Figure 4
The maps within the coastal management system dynamically update when the model data changes.

The user is presented with an initial front-end which provides access to screens for altering the sea level rise and population growth assumptions. The model is then run and maps of flood risk (fig. 4) or population growth can be displayed. The user is also able to manipulate the front-end to access statistical output. An example is given in figure 5 which shows a graphical matrix of estimated numbers of persons at risk from flood events with different return periods at various points in the future (determined by IPCC scenarios). The values given in figure 5 are based upon predicted sea level rise, storm return periods, and estimates of future population growth or decline within each management unit. Hazard scenario C represents an estimated sea level rise of 6.3 cm by 2050 and 13.13 cm by 2100, whilst scenario E corresponds to a rise of 39.68 cm by 2050 and 94.08 cm by 2100.

Figure 5
Output is also provided in the form of graphs and charts.



The package is being further developed into a fully operational system that contains information on a range of ecological, geomorphological, and socio-economic characteristics of the East Anglian coast. In this respect, it will operate in a similar fashion to Prospero Bay, but will be mapped onto a real-world geography. The use of a bespoke engine holds the potential to provide far greater functionality for coastal process modelling than would be possible with a traditional GIS alone. This is important as any coastal decision support system should be able to store the spatial and non-spatial attributes of each segment of the coastline, and then symbolically link the segment to all others, representing and modelling the inherent connectivity of coastal sections.

Conclusions

Whilst sophisticated coastal GIS exist, the dissemination of their results for use by professional decision-makers and stakeholders has not been well developed. Hence, advancements in GIS technology have not been matched by an ability to integrate the non-GIS experts' needs and expectations (Raal *et al.*, 1995). This article has illustrated how the results of a traditional workstation-based GIS analysis may be incorporated into a desktop decision support system for use by interested stakeholders and coastal managers. Although the volume of GIS associated coastal literature is increasing, the application of the technology within the coastal zone has been rather slow (Jones, 1995). The general transition of GIS from the workstation environment to mainstream desktop PCs is welcome news, and innovations such as Microsoft Data Map are blurring the distinction between specialized GIS packages and widely used database and spreadsheet software like Microsoft Excel. The development of coastal decision support packages such as that outlined here may well be a major step towards the more widespread day-to-day application of GIS technologies for the management of coastal resources (Raal *et al.*, 1995).

Despite the promise of the current innovations, a key issue that needs to be addressed if GIS are to realise their full potential for the management of coastal environments concerns data availability. The analysis of flood risks presented here could be refined by the availability of higher quality elevation data. Our models were based on the assumption that all areas of each management unit below the 5 m contour would be inundated in a flood event. Whilst this is a simplification of reality, detailed data on the internal topography of each management unit would be a pre-requisite for any attempt to undertake a more elaborate analysis. Obtaining such information is difficult as even the high quality Land-Form PROFILE™ digital database produced by the UK Ordnance Survey only provides contours at 5 m intervals. The improving availability of high resolution LIDAR (Laser Induced Direction and Range) derived digital elevation models is to be welcomed (Irish & White, 1998).

The increasing need for ICZM is a logical consequence of the rapid environmental and socio-economic changes occurring around the world's coastlines. For concerns such as coastal flood risk assessment, it is easy to see how GIS-based decision support systems may assist in the mitigation of property damage for existing structures, guide future development, and minimise resource degradation, thus saving money and possibly even lives (Hickey *et al.*, 1997). Despite this, it is generally true that there is still some way to go before the gap can be bridged between the evolution of an academic understanding of how such systems might work, and the provision of functional packages that are being widely used. However, time and resources invested in development today may pay rich rewards in the future.

Bibliographic references

Bartlett D.J., 1994. GIS and the coastal zone: present, past and future. Assoc. British Inf., London. AGI Pub., 3.

Bartlett D.J., Devoy R., McCall S., O'Connor I., 1997. A dynamically segmented linear data model of the coast. Mar. Geodesy, 20, 137-151.

Bower B.T., Turner R.K., 1998. Characterising and analysing benefits from integrated coastal zone management. Ocean Coast. Manage., 38, 41-46.

Brown A.F., Grice P.V., Radley G.P., 1994. Towards a strategy for the conservation of coastal habitats in north Norfolk; research paper 74. English nature, Norwich, Norfolk.

de-Kok J.L., Arifin T., Noor A., Wind H.G., Augustinus P.G.E.F., 1997. Systems analysis as a methodology for sustainable coastal-zone management in tropical countries. Tornai Mar. Sci. Technol. Bull., 8, 31-41.

Diment R., 1994. Tide turns for coastal management. Surveyor, 10, 25-29, November.

Dixon M.J., Tawn J.A., 1997. Spatial analyses for the UK coast, Proudman oceanographic laboratory. Bidston, internal report 112.

Green D.R., 1995. User access to information: a priority for estuary information systems. *In:* Proc. of CoastGIS'95, Bartlett D.J. (ed.), University of Cork, Ireland, 35-49.

Hickey R.J., Bush D.M., Boulay R.S., 1997. GIS supports coastal risk assessment. GIS World, June, 54-58.

Houghton J.T., Meira Filho L.G., Callander B.A., Harris N., Kattenberd A., Maskell K., 1996. Climate change 1995 - The science of climate change. Intergovernmental panel on climate change, Cambridge, England.

Hulme M., Raper S.C.B., Wigley T.M.L., 1995. An integrated framework to address climate change (ESCAPE) and further developments of the global and regional climate modules (MAGICC). Energ. Policy, 23, 347-355.

Irish J.L., White T.E., 1998. Coastal engineering applications of high-resolution lidar bathymetry. Coast. Eng., 35, 47-71.

Jones A.R., 1995. GIS in coastal management: a progress review. *In:* Proceedings of CoastGIS'95, Bartlett D.J. (ed.), University of Cork, Ireland, 165-171.

Leggett D.J., Jones A., 1996. The application of GIS for flood defence in the Anglian Region: developing for the future. Intern. J. Geogr. Inf. Systems, 16, 103-116.

Lucas A.E., 1996. Data for coastal GIS: issues and implications for management. Geogr. J., 39, 133-142.

MAFF (Ministry of Agriculture, Fisheries and Food), 1996. Flood and coastal defence. Ministry of Agriculture, Fisheries and Food, London.

MAFF (Ministry for Agriculture, Fisheries and Food), 1998. Shoreline management plans: a guide for coastal defence authorities. Ministry for Agriculture, Fisheries and Food, London.

Maslen J., Peltenburg J., Atkins S., 1996. Focusing in on the firths: Can GIS fulfil its potential for coastal zone management? *In:* Proc. ESRI Eur. Users Conf., London.

Meadowcroft I.C., Reeve D.E., Allsop N.W.H., Deakin R., Cross J., 1996. Risk assessment for coastal and tidal defences. *In:* Proc. of the 31st MAFF Conf. of river and coastal engineers, Keele, England.

Millar A., 1997. A vision for nature conservation on the north Norfolk coast. English nature, Norwich, Norfolk.

Openshaw S., 1995. Census Users' Handbook. GeoInf. Intern., Cambridge, England.

Pearce F., 1996. Crumbling away. New Sci., 21, 14-15, Dec.

Raal P.A., Burns M.E.R., Davis H., 1995. Beyond GIS: decision support for coastal development, a South African example. *In:* Proc. CoastGIS'95, Bartlett D.J. (ed.), University of Cork, Ireland, 273-282.

Ricketts P.J., 1992. Current approaches in GIS for coastal management. Mar. Pollut. Bull., 25, 82-87.

Shennan I., 1989. Holocene crustal movements and sea level changes in Great Britain. J. Quaternary Sci., 4, 77-89.

Shennan I., 1993. Geographic information systems and future sea level rise. *In:* Climate and sea level change, Warrick R.A., Barrow E.M., Widley T.M.L. (eds), Cambridge University press, Cambridge, England, 215-228.

Turner R.K., 1997. Ecological economics and project management in the coastal zone. Paper presented at the international symposium on large scale constructions in coastal environments, April, Norderney, Germany.

Turner R.K., Lorenzoni I., Beaumont N., Bateman I.J., Langford I.H, McDonald A.L., 1998. Coastal management for sustainable development: analysing environmental and socio-economic changes on the UK coast. Geogr. J., 164, 269-281.

Zeidler R.B., 1997. Climate change vulnerability and response strategies for the coastal zone of Poland. Climatic Change, 36, 151-173.

GIS as a tool to optimise integrated coastal defence management

Matthias Hamann, Jacobus Hofstede

Ministerium für ländliche Räume, Ernährung, Landwirtschaft und Tourismus des Landes Schleswig-Holstein, Postfach 1131, 24100 Kiel, Germany
matthias.hamann@landsh.de

Abstract

The possible consequences of global climate changes, especially an increase in sea level rise and/or higher storm surge frequencies, indicate increasing stresses for coastal areas. About 4,000 km^2 (25%) of the German Federal State of Schleswig-Holstein is situated less than 5 m above sea level, and may be characterized as coastal zone. Hence, coastal defence has a high priority in Schleswig-Holstein. In order to optimise coastal defence planning, the authorities decided to establish a geographic information system of all coastal lowlands in danger of being flooded during storm surges. The first part of this GIS was built up in the framework of a valuation study that was carried out to assess the number of people and the economic values in the flood prone areas. In this presentation the methods and the results of this study, especially the use of GIS spatial analysis tools for assessing the damage potential, will be presented.

Résumé

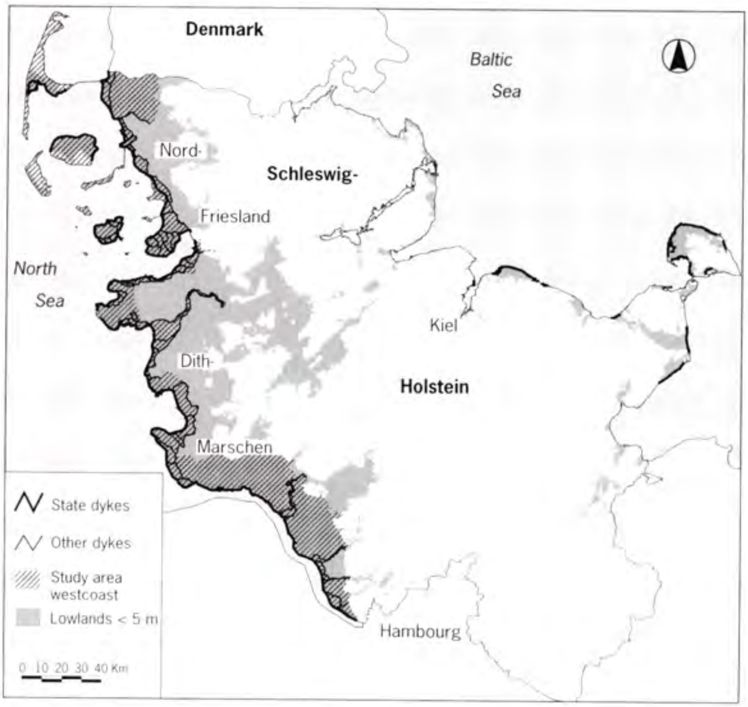
Les conséquences possibles de l'évolution climatique pronostiquée, tout particulièrement l'accroissement de la montée du niveau de la mer et de l'activité des tempêtes, peuvent signifier un danger pour les régions côtières. Une grande partie du Land du Schleswig-Holstein a le caractère de zone côtière. Les zones basses s'élevant à moins de 5 m d'altitude recouvrent une surface d'environ 4 000 km^2 (soit 25 % de la surface totale du Land). Aussi la protection des côtes a-t-elle une grande importance dans le Schleswig-Holstein. Pour en optimiser la planification, les autorités publiques concernées ont décidé de développer un SIG pour les régions menacées par les raz de marées. La première composante de ce SIG est une étude sur les relevés d'information sur les risques d'inondation. Les méthodes et les résultats de cette étude, et particulièrement l'utilisation des fonctions d'analyses du SIG dans le cadre des procédés de relevés, sont présentés.

Introduction

The German Federal State of Schleswig-Holstein lies between two seas, the Baltic Sea to the East and the North Sea to the West (fig. 1). In all, the coastline measures 1,099 km, 515 km of which are occupied by dykes. Without dykes up to 25% or about 3,994 km^2 of the total area of Schleswig-Holstein could become flooded during extreme storm surges. To prevent this, the coastal defence authorities established in 1963 a masterplan "Dike-reinforcement, dike-shortening and coastal defence in Schleswig-Holstein" that represents the legal, technical and financial concepts for coastal defence works in Schleswig-Holstein. The plan is described in detail by Hofstede (1993). It has been updated in the years 1977 and 1986.

The coastal defence masterplan is based upon assumptions about the hydrographic conditions (extreme water levels, wave run-up and secular sea level rise) that are supposed to have validity until the year 2,000. Hence, by this year a new masterplan with the latest assumptions has to be established. One important aspect that has to be considered is a possible anthropogenic climate change and its hydrographic consequences. Furthermore, population and values in the protected areas have increased considerably since 1963. Finally, environmental, touristical as well as cost-benefit aspects have gained much more importance over the last decades. In consequence, the new coastal defence masterplan must consider other interests in the coastal zone as well as cost-benefit aspects, and it should be flexible enough to respond quickly to changing hydrographic prognoses.

Figure 1
The German Federal State of Schleswig-Holstein with the valuation study area.



To meet all these requirements, a high-quality database with all relevant spatial and statistical data is essential. However, only a small part of the necessary information is readily available. Most of the data lie scattered in various authorities and in different formats. Before they can be used, these disparate data sets must be compiled and prepared in an appropriate, homogeneous format. Statistical data need to be georeferenced so that they can be correlated to other spatial data (digital terrain models, etc.). As stated by Allen *et al.* (1995) one of the well-recognized reasons for using a geographic information system (GIS) is the integration of disparate data sets. According to Bartlett (1994), GIS has great potential to optimise the value of information as a resource within an organization.

In consequence, the coastal defence authorities in Schleswig-Holstein decided to use GIS in order to establish a digital database (Coastal Defence GIS, CD-GIS) of all coastal lowlands in the State. As a first step in the establishment of this CD-GIS, a valuation study of all coastal lowlands in danger of being flooded during extreme storm surges was conducted (Hamann, 1994; Hamann & Klug 1998; Hamann & Hofstede 1998). After an overview of the study area, this paper deals with this valuation study.

Regional setting

Schleswig-Holstein is the most northerly State in Germany. It has an area of 15,731 km^2 and a population of about 2,700,000. As the State is situated between two seas, a large part of it may be characterized as coastal zone. Within this zone, most of the population is concentrated, *e.g.* in the harbour cities of Kiel and Lübeck.

The Baltic coastal landscape constitutes a bay-and-headland coast of glacial origin, interrupted by some large fjords. During the Holocene transgression, the irregular glacial-moraine topography was smoothed and straightened by processes of headland erosion and littoral sediment transport into the bays and fjords. Today, the Baltic Sea coastline of Schleswig-Holstein measures 535 kilometres. The length of the lowland coastline is 348 km, another 148 km is occupied by cliffs and the rest by various (anthropogenic) forms. The total area of coastal lowlands (below German Ordnance Datum GOD +3.0 m) amounts to 345 square kilometres. 92,000 people live within this area.

The westcoast of Schleswig-Holstein is part of the Wadden Sea that fringes the Danish, German and Dutch coastlines between Skallingen in Denmark and Den Helder in the Netherlands. The formation of the Wadden Sea with its barrier islands, tidal flats and coastal marshes started shortly after 8,000 BP when the sea had risen above the GOD -20 m level (Streif, 1989). As a result of the Holocene transgression up to 35 m thick sequences of coastal sediments were deposited in the area. Today the Wadden Sea of Schleswig-Holstein occupies an area of 2,759 km^2, 434 km^2 of which are islands and saltmarshes. The length of the coastline measures 564 km, 297 km of which belong to the mainland and 267 km are island coastlines. Intensive dyking over the last nine centuries resulted in the reclamation of an area of about 3,514 square kilometres. The study area along the westcoast was restricted to the area between the State dykes and the so called second dyke-line (fig. 1). This second dyke-line is situated inland from the first (State) dyke-line. In the case of a dyke-breach only the area between the first and second dyke-line may be flooded. This area amounts to 1,441 km^2, in which 126,000 people live.

GIS for coastal defence management in Schleswig-Holstein

Today GIS are utilised in almost every field, where geographical data and spatial information are of importance. The application of GIS for coastal zone issues has been described in great detail by Bartlett (1994). Jones (1995) underlines the great potential of GIS, especially its data-integration functionalities, for integrated coastal zone management. In Germany, Schauser (1993) used GIS for a study on spatial planning in the coastal zone of Schleswig-Holstein. Sterr & Schmidt (1995) determined the possible effects of global climate changes for the German coastal zone using GIS.

Methodology

As stated in the introduction, the coastal defence authorities decided to use GIS for the establishment of a digital coastal defence database (CD-GIS). It will consist of several modules, *e.g.*, a digital coastal register, a digital terrain model (DTM), a scenario-module and a saltmarsh-module. The geographical framework of the CD-GIS was established in the course of a valuation study of the lowlands in danger of being flooded during storm surges. The main objective of the valuation was the determination of the consequences of a possible flooding of coastal lowlands, especially the assessment of possible damage and depreciation in value. On the basis of this study it will be possible to conduct cost-benefit analyses for coastal defence works.

The valuation study was restricted to the establishment of a geographical framework of the coastal lowlands (including the DTM) and an assessment of economic values in these lowlands. Different studies were used as a methodological basis (Ball *et al.*, 1991; Karas *et al.*, 1991; Penning-Rowsell *et al.*, 1992; Klaus & Schmidtke, 1990). They differ in their scales of interest and detail, in their databases as well as in their methodologies. Gewalt *et al.* (1996) differentiate between micro, meso, and macro-scale studies. The micro-scale approach is applied mostly in local studies. The meso-scale approach is used when larger areas are investigated, as for instance coastal zones on a regional level (Schmidtke, 1995). The macro-scale approach is applied at a national or international level. Micro-scale studies can normally use detailed enumerations on damage potential, *e.g.* the calculation of housing capital based on field mappings of land use and buildings for each parcel. As a result of the larger study areas, this is normally not practicable for meso-scale studies. They must rely on aggregated data sets, such as statistical data, *e.g.* municipal and district statistics.

For Germany, Klaus & Schmidtke (1990) delivered a meso-scale expert opinion (cost-benefit analysis) for coastal defence works in the "Weser-marsch-area", Lower Saxony. This pilot study functioned as a methodological guide for a coastal defence valuation study that was conducted in the German Federal State of Mecklenburg-Vorpommern (Gurwell, pers. comm.). For reasons of comparison, the same expert opinion was used in Schleswig-Holstein.

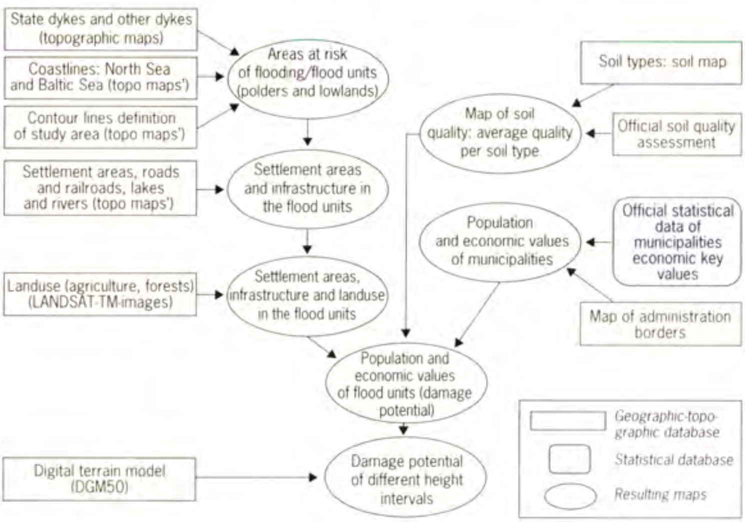
Being a meso-scale study, the valuation is based on aggregated data sets (official municipal statistics). Using the GIS, the following data from different sources were compiled and processed to create a homogeneous database (fig. 2):

• physical geographical data:
- elevation information from a DTM,
- topographic structures from maps, scale 1:50,000 (roads, settlements etc.);

•land-use data (Landsat-TM images);

•socio-economic data (municipal and district statistics):
- inhabitants,
- houses,
- roads infrastructure,
- motor vehicles,
- livestock,
- quality of agricultural soils,
- touristic capacity (number of beds),
- places of work and employees for 10 different sectors of economy,
- gross increment value and tax yield (running economic results).

Figure 2
Data sources and data flow in the valuation study.



The integration of these data with statistical key values results in the entirety of all protected values per municipality. For instance, the multiplication of the number of inhabitants by the average housing capital per inhabitant (key value) results in the housing capital per municipality.

In a next step, the study area was divided into so called flood units (fig. 3). Each flood unit represents the area that becomes flooded when a single dyke is breached during a storm surge. Each unit is separated from other flood units by other dykes (polders at the westcoast) or higher grounds (Baltic coast). Normally, the flood units do not fit with the municipalities. However, for coastal defence planning purposes it is important to know what damages are to be expected for each flood unit. Hence, the values per municipality were broken down to these units. For this, the method used in the "Wesermarsch-study" was modified to local circumstances. Assuming that economic values and inhabitants are primarily located in residential sites, the proportion (%) of residential sites per municipality within each flood unit was

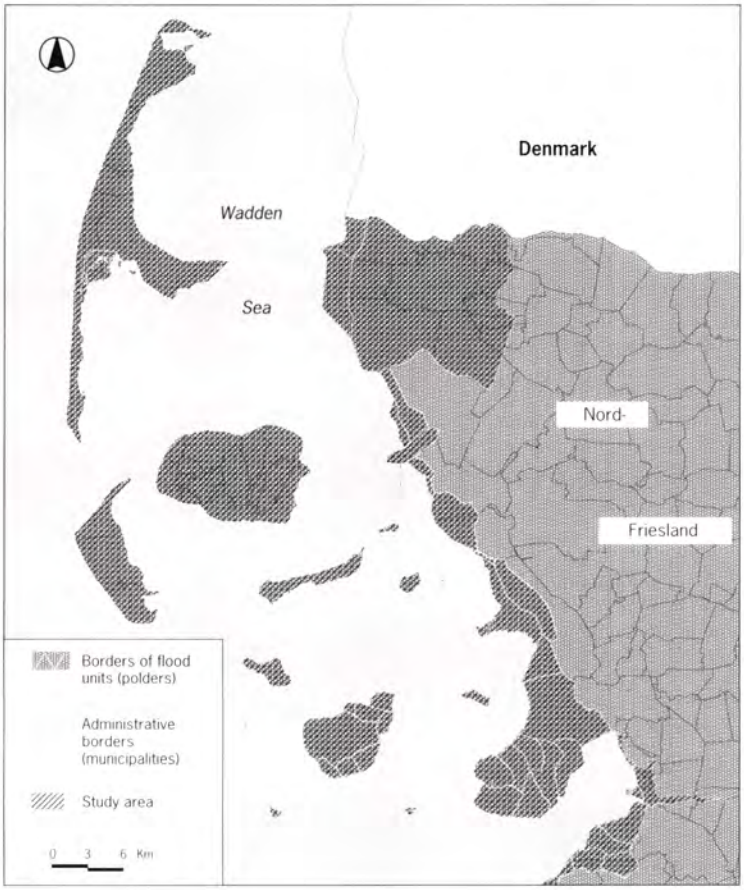


Figure 3
Municipalities and flood units in the district of Nord-Friesland.

established. Similarly the proportion (%) of agricultural area or rather agricultural values per municipality for each flood unit was determined. With the established percentages the total values per flood unit could then be calculated. Furthermore, with the DTM the values for different height intervals within each flood unit could be appraised.
Within the framework of the valuation study a micro-scale analysis was carried out for one municipality at the westcoast (Reese, 1997). The study was based upon a detailed survey of the above mentioned values for each parcel of land in the municipality of St. Peter-Ording. The results were then compared with the "Wesermarsch-study" in order to optimise the meso-scale valuation methodology.

Results

Table 1 displays the results of the valuation in summary. In all, about 218,000 people live in the study area, which comprises the are between the State dykes and the second dyke-line at the westcoast, and the lowlands below GOD + 3.0 m at the Baltic coast. The area in danger of being flooded during extreme storm surges along the westcoast is about four times as large as along the Baltic coast. In spite of this the number of people affected along the Baltic Sea coast is relatively high. The total of protected values within the study area amounts to 57 billion German marks (about 29 billion Euro), more than half of which is concentrated in the Baltic Sea coastal lowlands. The reason for this is the high concentration of people and economic values in the coastal cities along the Baltic Sea. Large parts of the town centres of the cities of Kiel, Lübeck, Flensburg and Eckernförde with their harbour industries are situated below GOD +3.0 m.

Table 1 - Area, number of inhabitants and protected values in the study area.

	Westcoast	Eastcoast	Total
Area in km^2	1441.600	344.910	1786.510
Inhabitants	126,574	91,606	218,180
Housing capital in billion Euro	5.734	4.532	10.266
Household goods in billion Euro	2.293	1.813	4.106
Capital assets in billion Euro	5.625	8.148	13.773
Stock assets in billion Euro	0.373	0.541	0.914
Total in billion Euro	14.025	15.034	29.059

With the GIS the calculated values for each flood unit can now be selected, analysed and presented in an appropriate form. Figure 4 displays the population density for each flood unit in the district of Nord-Friesland. The harbour town Husum and the Isle of Sylt show the highest population densities. On the Isle of Sylt this high density is a result of the large number of second houses (holiday houses, etc.). The agricultural marsh areas along the mainland coast on the other hand have relatively low population densities.

For coastal defence planning purposes, the summation of all single values per flood unit is of high relevance. Table 2 shows the results for three different flood units (Marienkoog, Wilstermarsch, Kiel) in the study area. From this, the great heterogenity of the flood units becomes apparent. The Marienkoog is a sparsely populated, agricultural polder along the westcoast with a relatively low damage potential (most of the values are agricultural values). The Wilstermarsch is a relatively large flood unit (fig. 5), characterized by some urban settlements and a relatively high number of industrial enterprises. This flood unit is special in that it has no second dyke-line. Furthermore, a large part of the Wilstermarsch is situated well below GOD. In the case of a dyke-breach, a large lake would appear and remain for a longer time period after the storm surge. The costs for reparation normally increase with the duration of the (saltwater) flooding. As a result, damages would be specifically high in this flooding unit. The third example shown in table 2

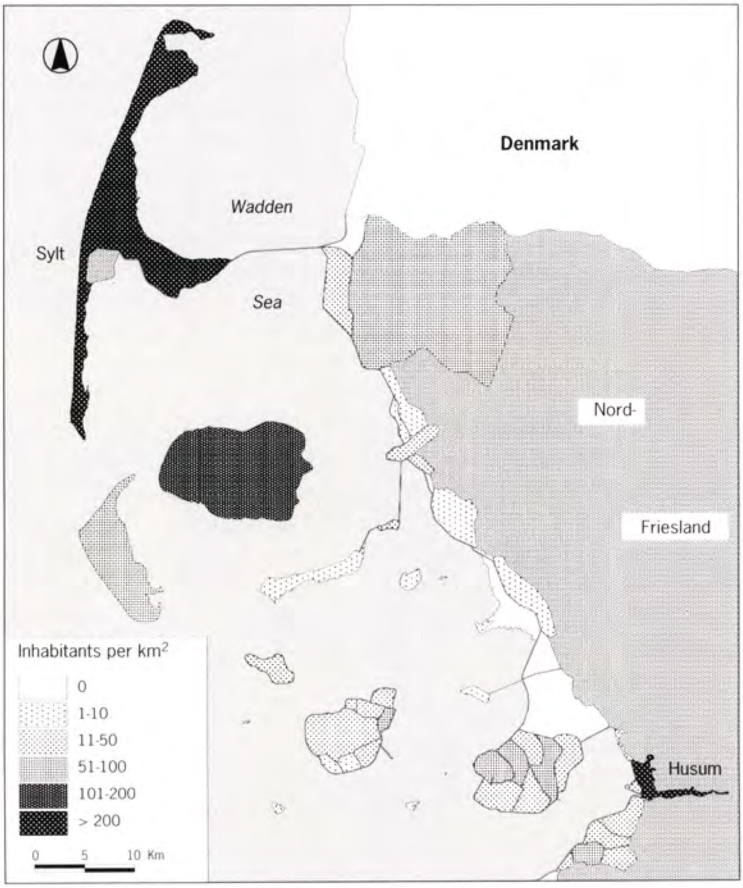


Figure 4
Population density of the flood units in the district of Nord-Friesland.

is the harbour city of Kiel along the Baltic Sea coast. This relatively small flood unit comprises the inner city of Kiel as well as some major harbour industries. Hence, the number of inhabitants and economic values in this flood unit are very high.

Table 2 - Results of the valuation for three different flood units.

Flood unit	Marienkoog	Wilstermarsch	Kieler Förde
Area in km^2	6.92	193.05	8.50
Inhabitants	32	13,140	36,969
Values in Euro Housing capital and household goods	1,970,436	754,649,421	2,464,001,401
Agricultural assets (incl. livestock)	1,502,598	35,136,612	2,121,993
Capital assets of processing industries, power producing industry and building trade	5,267	890,101,428	2,238,833,136
Capital assets of service industries, trade and commerce	57,872	279,853,089	2,615,723,910
Stock assets	48,344	78,285,443	322,475,993
Motor vehicle assets	100,255	39,505,288	90,544,018
Total	3,684,772	2,077,531,281	7,733,700,451

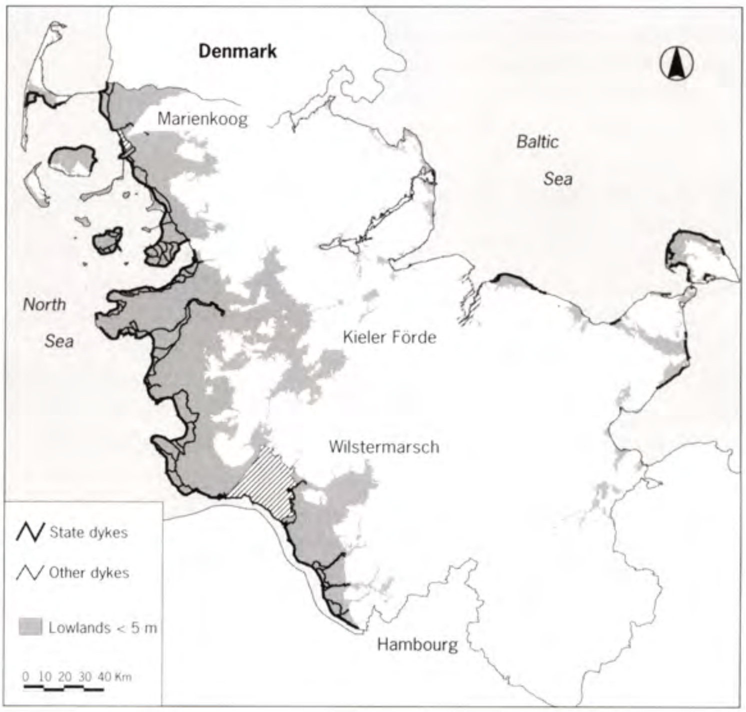


Figure 5
Location of the three different sample flood units shown in table 2.

Concluding remarks

The use of GIS for the valuation study turned out to be very time consuming. Almost 90% of the total project time were used to compile and process the raw data into a homogeneous database. However, when this database was established, the powerful analysis functionalities of GIS allowed for an accurate, high resolution calculation of total protected values per flood unit and height interval. With this, it is possible to determine optimal technical solutions (in a cost-benefit manner) as well as to establish priority lists for coastal defence works. Furthermore, with the cd-GIS it will become possible to simulate the consequences of different climate and land-use scenarios for coastal defence planning. Potential conflicts between user functions (for instance coastal defence, tourism or nature conservation) and the natural system can be identified by means of impact matrices and overlays (Van der Weide, 1993). In conclusion, GIS is a powerful tool for integrated coastal defence management.

Bibliographic references

Allen J.R., Shaw B., Lange A.F., 1995. Modeling shoreline dynamics at sandy hook, New Jersey, USA using GIS/GPS. Proc. Int. Symp. CoastGIS'95, University College, Cork, Ireland, 191-228.

Ball J.H., Clark M.J., Collins M.B., Gao S., Ingham A., Ulph A., 1991. The economic consequences of sea level rise on the South Coast of England. GeoData institute report to the Ministry of Agriculture, Fisheries and Food, unpublished, 2, 139-140.

Bartlett D., 1994. GIS and the coastal zone: past, present and future. Assoc. Geogr. Inf. Pub., 3, 36 p.

Gewalt M., Klaus J., Peerbolte E.B., Pflügner W., Schmidtke R. F., Verhage L., 1996. EUROflood - Technical annex 8. Economic assessment of flood hazards - Regional scale analysis-Decision support system (RSA-DSS). München, 37 p.

Hamann M., 1994. Voruntersuchung zur Erstellung eines Bewertungsgutachtens der potentiellen Überflutungsgebiete in Schleswig-Holstein. Unpublished report, FTZ Westküste, CAU Kiel, 34 p.

Hamann M., Klug H., 1998. Wertermittlung für die potentiell Sturmflutgefährdeten Gebiete an den Küsten Schleswig-Holsteins. *In:* Preu C. (ed.), Aktuelle Beiträge zur interdisziplinären Meeres- und Küstenforschung, Vechtaer Studien zur angewandten Geographie und Regionalwissenschaft 20, Vechta, 63-70.

Hamann M., Hofstede J.L.A., 1998. GIS-Applications for integrated coastal defence management in the Federal State of Schleswig-Holstein, Germany. *In:* German Geogr. Coast. Res., The last decade, Kelletat D. (ed), Tübingen, 169-182.

Hofstede J.L.A., 1993. Coastal defence policy in the Federal State of Schleswig-Holstein: adapting to changing hydrographic conditions. Proc. Int. Workshop Seachange'93, VI 3-VI 14.

Jones A.R., 1995. GIS in coastal management: a progress review. Proc. Int. Symp. CoastGIS'95, University College, Cork, Ireland, 163-178.

Karas J.H.W., Turner R.K., Bateman S., Doktor P., Brown D., Maher A., Bateman I., Roberts L.J., 1991. Economic appraisal of the consequences of climate-induced sea level rise: A case study of East Anglia, University of East Anglia report to the Ministry of Agriculture, Fisheries and Food, unpublished, 222 p.

Klaus J., Schmidtke R.F., 1990. Bewertungsgutachten für Deichbauvorhaben an der Festlandsküste - Modellgebiet Wesermarsch. Untersuchungsbericht im Auftrag des Bundesministers für Ernährung, Landwirtschaft und Forsten, Bonn, 150 p.

Penning-Rowsell E.C., Green C.H., Thompson P.M., Coker A.M., Tunstall S.M., Richards C., Parker D.J., 1992. The economics of coastal management - A manual of benefit assessment techniques (The yellow manual). London, 380 p.

Reese S., 1997. Auswirkungen eines potentiellen Deichbruchs auf einen Fremdenverkehrsort am Beispiel von St. Peter-Ording - eine touristisch orientierte Schadensanalyse im Rahmen eines Wertermittlungsverfahrens für die Überflutungsgefährdeten Küsten Schleswig-Holsteins unter dem Aspekt des Meeresspiegelanstiegs. Unpublished diploma thesis, Institute of Geography, University of Kiel, 155 p.

Schauser U.H., 1993. Das Wattenmeer und sein Umfeld als Objekt einer Übergreifenden Raumplanung in Schleswig-Holstein - eine anwendungsorientierte Studie unter Einsatz eines geographischen Informationssystems. Berichte Forschungs- und Technologiezentrum Westküste 3, Büsum, 225 p.

Schmidtke R.F., 1995. Sozio-ökonomische Schäden von Hochwasserkatastrophen. Darmstädter Wasserbau-Mitteilungen H. 40.

Sterr H., Schmidt K., 1995. Auswirkungen des Klimawandels auf den deutschen Küstenraum. Geographische Rundschau 47. Jg. H. 2, Braunschweig, 105-112.

Streif H.J., 1989. Barrier islands, tidal flats, and coastal marshes resulting from a relative rise in sea level in East Frisia on the German North Sea coast. Proc. KNGMG Symp. "Coastal lowlands, geology and geotechnology", Kluwer Acad. Publ. (ed.), Dordrecht, 213-223.

Van der Weide J., 1993. A system view of integrated coastal management. Ocean Coast. Manage., 21, 129-148.

A GIS application for the study of the morphodynamics in the shoreface area of the German Bight: methods and problems

Peter Hüttemeyer

Lower Saxony State Agency for Ecology, Coastal Research Station, An der Mühle 5, 26548 Norderney, Germany - huttemeyer@gmx.de

Abstract

In the shoreface of the German Bight an increase of depth and a related steepening of the profile has been observed over several decades. A negative influence to coastal protection is expected. Extensive evaluations of sea survey data were started to understand the underlying morphological processes. The sea survey data are evaluated with a GIS and found inaccurate for detailed morphological studies. Statistical method for an evaluation of the data quality, morphodynamics and a concept for a morphodynamic zonation of the shoreface based on statistical parameters are presented. The results achieved with a GIS and the developed evaluation methods are more accurate and extensive than with conventional methods.

Introduction

The German Bight coast mainly consists of sandy sediments and is susceptible to the attacking forces of current and swell. In the shoreface swell energy is absorbed and sand is transported. The transported sand is part of the supply of the islands and the coast and contributes to their conservation. In different local examinations of sea surveys an increase of depth over time was observed, resulting in a long-term steepening of the shoreface profile (Stephan *et al.*, 1998; Verwaest. *et al.*, 1999). Because of the steepening, forces attacking beaches, dunes and dykes are expected to increase. Furthermore, a reducing influence on the transport of sand parallel to the coastline, which is important for the preservation of the islands, is expected.

To study the steepening process and the morphodynamics in the shoreface area sea survey data of the German Bight collected during the last 50 years were examined with the use of GIS-software (several ESRI products) and evaluation methods considering the special character of sea survey data were developed. Used GIS methods, the problem with the quality of the sea survey data, the importance of metadata and first results are represented.

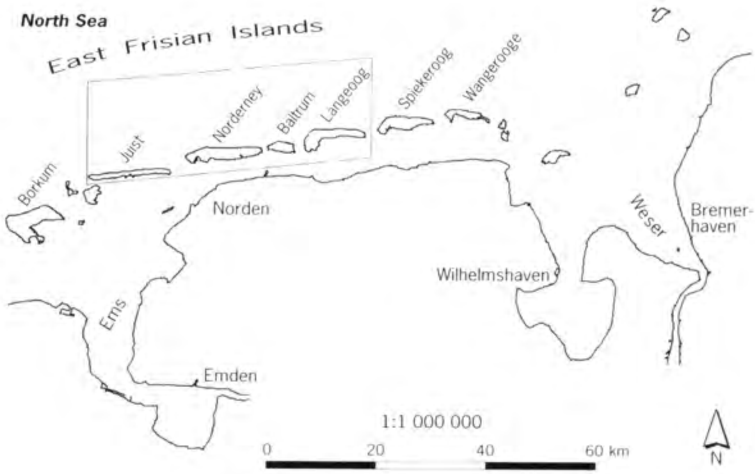


Figure 1
Study area East Frisian Islands.

Sea surveys and Digital Terrain Models (DTM)

In the last decades, sea surveys of the dynamic shoreface for the security of shipping were periodically carried out. Sea surveys result in data points of depth below sea level which are stored in maps. Results from more recent surveys are also stored as digital data. To build a GIS database 175 maps were digitized. The available digital data was also imported to the GIS. Data conversions, like the reference to a uniform co-ordinate system and the conversion to a uniform reference gauge level, were conducted with GIS tools. Thus, a uniform database with more than 6.5 million single points was constructed.

For all surveys DTM's were calculated and checked for plausibility. Results from different methods of DTM computation (*e.g.* different grid cell sizes and different statistical procedures such as kriging, inverse distance or search radius) were compared with each other. They were found to be similar for the relatively flat and unstructured shoreface. However, for areas with distinct structures, such as channels in the Wadden Sea, the method of DTM calculation has a significant impact on the resulting terrain model. For the shoreface it was found that extreme values are best represented by the method of irregular triangulation. This method yields estimates of error which are needed when data quality is evaluated. DTM calculation results were stored in a regular grid (100 m*100 m). The width of this grid was chosen to be smaller than the distance between individual measurement (about 200 m). All further analyses are based on this grid. The flow of data from the maps to the evaluations is illustrated in figure 2. This concept is flexible with respect to different evaluations, supplements and corrections. It allows fast calculations of differences, balances, etc. Thus, calculations for any specific area can be spatially represented and analysed conveniently within the GIS environment.

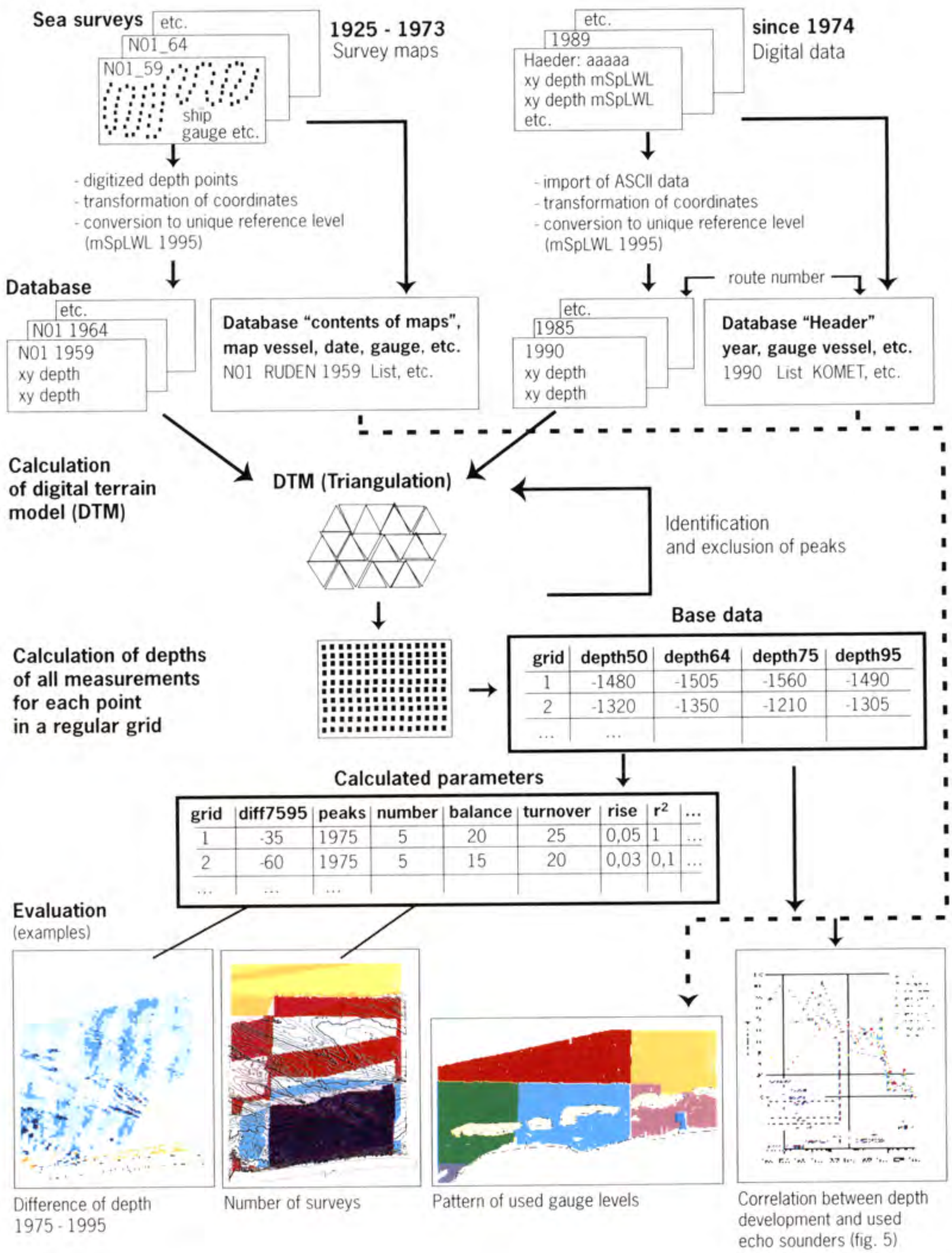


Figure 2 - Flow of data, processing and evaluation of sea surveys with a GIS for morphodynamic investigations in shoreface areas.

If available, additional data about each survey, such as reference gauge levels, measurement techniques, assigned ship, date, and time, were included into the relational GIS database. During evaluation and interpretation of the results this metadata turned out to be very important. A systematic influence of different echo-sounding systems was found with the help of that metadata (fig. 5).

Evaluations and data quality (examples)

In this chapter some examples of the methods used for further evaluations of the GIS database are described. To enable regional comparisons, evaluations were conducted for more than 5 000 km^2 along the shoreface of the German Bight. All evaluations are based on the same GIS database.

Changes of depth

On the basis of the grid database changes in depth between two different surveys can be calculated and represented spatially within the GIS. With these changes of depth mass balances can be calculated for any area. The result is a pattern with the routes of individual measurement routes due to the low quality of the survey data. Deviations are as high as ±50 cm and are mainly caused by an inaccurate reduction to the reference gauge level. Some more causes of a number of inaccuracies was found with the help of the survey metadata. Moreover, calculations yield an average increase of depth of approximately 70 cm within 20 years. For the represented area (208.9 km^2), this corresponds to a sediment loss of more than 146 million square metres. Because of the obvious inaccuracies in the sea survey data the result of such a sediment loss is doubtful.

Profiles vs. average change of depth

Figure 3 shows profiles which were calculated from the grid database. Despite some oscillations, an increase of depth over time is observed. Some of the oscillations can be assigned to inaccuracies in the survey data. Because of the influence of these inaccuracies, the general suitability of profiles to describe changes in the shoreface elevation must be questioned. To obtain a more reliable picture, average changes of depth were calculated for various sub-areas of the shoreface extending over several km^2 (fig. 4). From zones of a certain shoreface elevation (*e.g.* -6 to -8 m), average changes of depth towards the most recent survey campaign were calculated. Compared to the profiles in figure 3, the influence of inaccuracies is reduced. In figure 4 an almost constant increase of depth in the shoreface can be observed. Individual survey campaigns deviating from the general trend can be identified and it can be concluded that the increase of depth is remarkably larger in the -6 m to -8 m zone than it is in adjacent, deeper areas. This is a general observation for all studied areas which cannot be recognized from elevation profiles of the type shown in figure 3.

Figure 3
North-South profile
in the shoreface of Norderney.

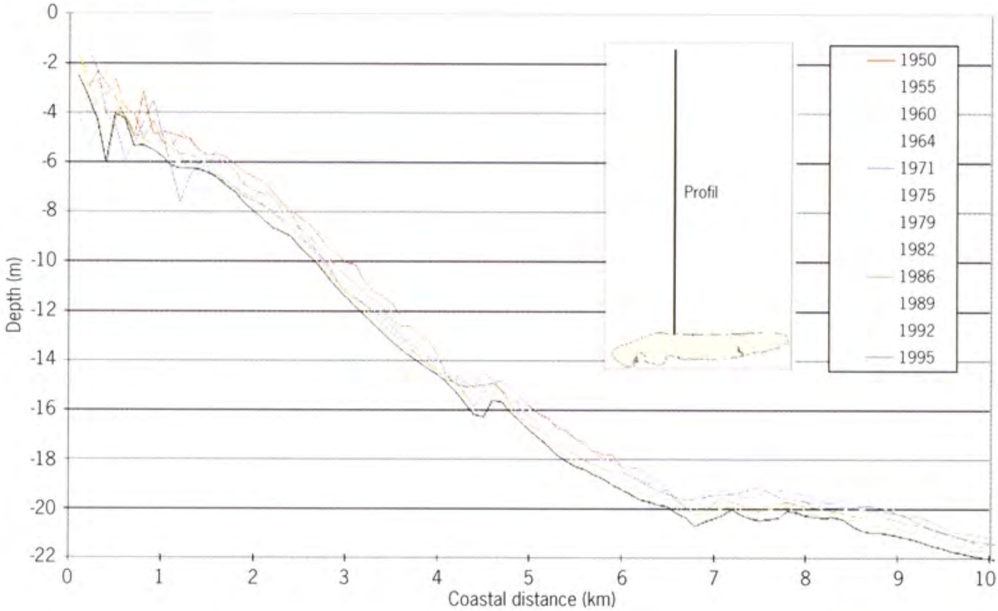
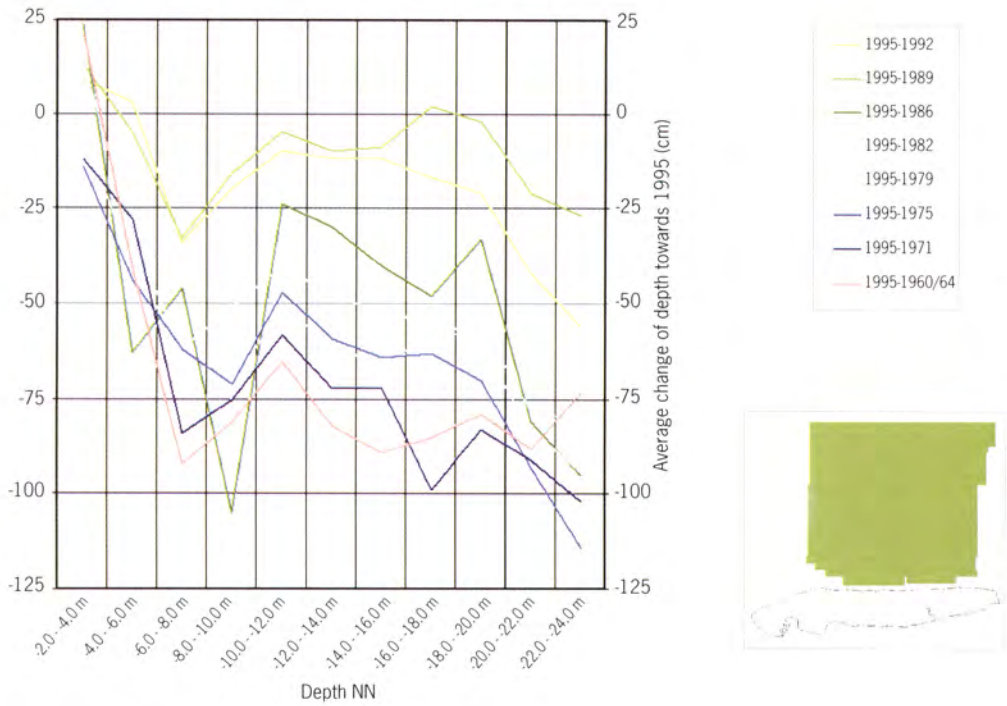


Figure 4
Average change of depth
in the shoreface of Norderney
1960-1995 (area 95,5 km²).

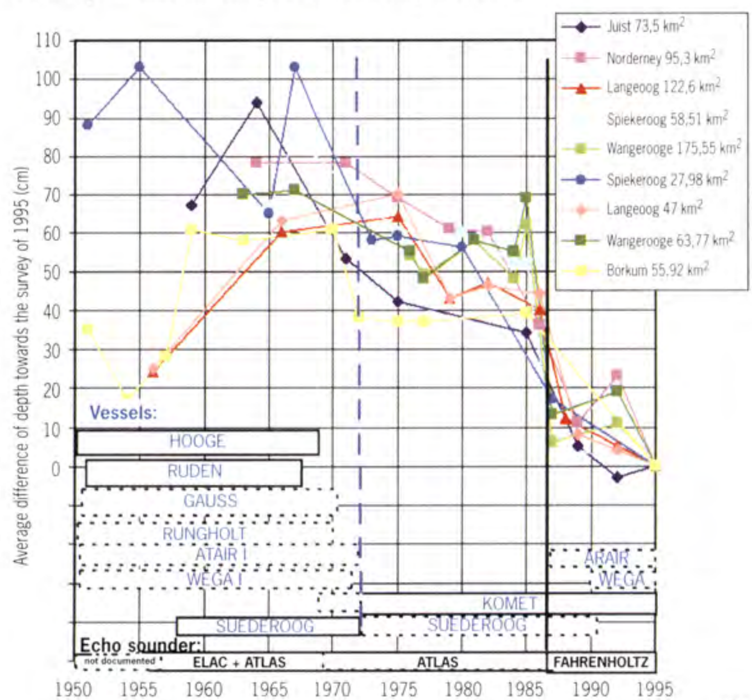


Average change of depth and measurement technique

Extensive computations covering several 1 000 km^2 of the German Bight showed almost similar increases of depth in the shoreface for all coastal sectors over several decades. For individual coast sectors covering limited areas and local investigations increases of depth to the extent found in the data may be realistic. During the research described in this paper, results from survey campaigns of the shoreface area of the entire German Bight (> 5 000 km^2) were processed and extensive sediment balances were calculated. Computations resulted in a significant loss of sediment for the entire shoreface of the German Bight. Because of the total amount of sediment loss (>2 200 million m^2 over a period of 20 years) and the absence of any accumulation areas within the shoreface of the German Bight, it is very likely that these results are caused by errors in the database (Hüttemeyer *et al.*, 1998).

In search of an explanation for the implausible increase of depth the additional information or survey metadata turned out to be of key importance. A relation was found between elevation and the type of echo sound device used during survey campaigns. For various shoreface areas, extending from 27.98 km^2 to 175.55 km^2, the average difference in elevation from every survey campaign compared to the 1995 survey was calculated (fig. 5). In the lower part of the figure the echo sounders and measurement ships used are specified. The influence of different survey techniques and ships on measured elevations becomes evident. Particularly, the change of echo sounders in the year 1986 caused increase of depth of about 0.3 m to 0.4 metres. Additional, statistical investigations revealed some more minor systematic influences of different survey techniques used in the past (Hüttemeyer *et al.*, 1999).

Figure 5
Average change of depth and measurement techniques in the shoreface of the East Frisian Islands.



Statistical parameters for the description of the morphological development

Changes of depth are conventionally expressed by retreating or progressing isolines. Regressions and correlation coefficients are calculated to express and underline the assumed trend. However, because of the described inaccuracies in sea survey data, the position of an isoline on a map representing the relatively flat sea ground is not very reliable. Another way to describe changes in depth are profiles. The limited usefulness of such profiles to describe data accuracy has been discussed in the previous chapter.

Statistical parameters can be calculated for any area like grid cells of any size or morphological units like ebb tidal deltas, any part of the seaground or tidal basin. A small area leads to a more differentiated result, however, it is disturbed by a higher noise level (fig. 7, 8). A central problem for any work with sea survey data is the identification and elimination of incorrect data. For this work, locally differentiated threshold values were developed to automate the identification of peak values (incorrect measurements in fig. 6).

Figure 6
Examples for different time series of morphological changes.

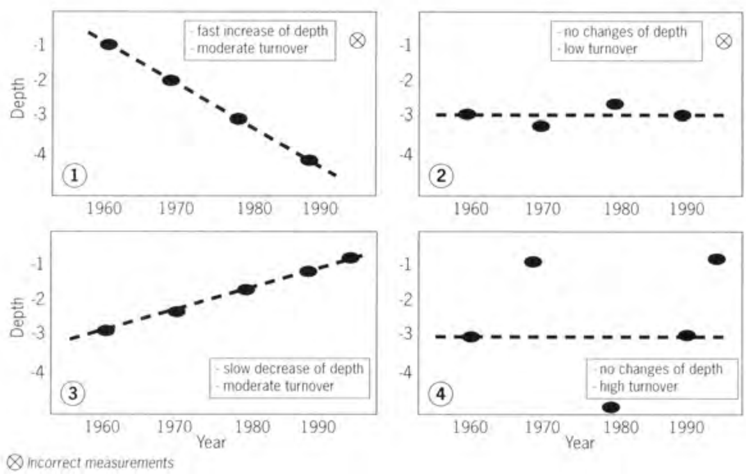


Table 1 - Statistical parameters for the examples.

Example Nr. (see fig. 6)	Number of surveys (without peaks)	Year(s) of incorrect surveys	Turn over (total)	Average turnover per survey [TURN]	Balance (oldest minus youngest survey)	Balance /average turnover per survey	Regression in-or decrease per year [REG]	Correlation coefficient r^2	TURN/ [REG]
1	4	1995	3.0	0.75	-3.0	-4.0	-0.1	1.0	-0.133
2	4	1995	0.6	0.15	±0.0	±0.0	0.004	0.1	0.027
3	4	-	2.0	0.5	+1.5	+3.0	0.05	1.0	0.100
4	5	-	14.0	2.8	-2.0	-0.7	0.0	0.002	0.000

The spatial distribution of any of the calculated parameters can immediately be visualized within the GIS. Figure 8 illustrates the spatial distribution of the calculated average sediment turnover as described below. The highest turnover is occurring in the foreshore and lowest values occurring in the deeper zones. Some local modifications can be observed, *e.g.* the increase of sediment turnover in areas of moving ridges in the central parts of the illustration. Beside morphological changes, the influence of incorrect sea survey data is obvious in this illustration. The identification of incorrect data has to be improved.

Examples for statistical parameters

Changes of depth and mass balances are not the only parameters to describe morphological changes and activities. The use of a GIS enables one to determine a variety of more accurate parameters in a very effective way. Some of these parameters are discussed in this chapter.

Sediment turnover

The sediment turnover in a grid cell can be defined as the change in the shoreface elevation between all survey campaigns. It is a measure for the morphological activity in an area (Hofstede, 1991). Sediment turnover is influenced by the number of surveys and the time between consecutive survey campaigns. Calculation of the average sediment turnover per survey (*i.e.* sediment turnover divided by the number of surveys) for every grid cell leads to more accurate description of the morphological activity.

Sediment balance

The sediment balance for a grid cell or any other area is he difference in volume between the oldest and youngest survey campaigns. Incorrect survey data has a significant influence on sediment balance. Therefore, only limited conclusions can be drawn from the results of sediment balance calculations.

Sediment balance - Sediment turnover ratio

The ratio of sediment balance and sediment turnover ranges from 0 to ± 1.0. By definition, sediment balance cannot be larger than sediment turnover. When the ratio is close to unity, all changes in elevation over time take the same direction, *i.e.* in the corresponding grid cells either only erosion or only accumulation occurs over time. Values close to zero indicate that erosion and accumulation alternate. However, similar to sediment balance the balance-turnover ratio is influenced considerably by inaccurate survey data.

Regression (in-or decrease) of shoreface elevation per year, correlation coefficient

From a time series of shoreface elevation, a trend can be calculated. The trend is described by two parameters: the gradient and the coefficient of the determination, r^2. The gradient expresses the velocity of the increase or decrease in depth. The coefficient of determination expresses how accurately the data is described by the trend line. A problem of this analysis is that a trend line assumes a continous trend during the entire time period, which is not necessarily the case for the investigated shoreface. Also, a minimum number of survey campaigns must be available for a given grid cell to obtain a reliable result. The spatial distribution of the regression parameters visualized within the GIS leads to interesting results.

Synthetic parameters

When some of the parameters described above are combined, a variety of synthetic parameters can be generated. Resulting combination parameters can be superior to conventional parameters. For example, a combination of the gradients (correlation coefficient and average turnover) promises a good description of the morphodynamic characteristics of a certain area.

Conception of a morphodynamic zonation in the shoreface area

Conventionally morphological zones in the shoreface are delineated by depth and/or occurring morphological forms. A grid database in the GIS enables a more detailed zonation. Based on calculated parameters, as described above, the shoreface can be divided into areas of different morphodynamic activity and sediment dynamics. The morphodynamics in each zone is described by several typical, quantified values, as described in principle in table 2. The proposed morphodynamic zonation still needs some improvements and refinements. Especially the selection, combination and weighting of the parameters are still underway, but the first results are promising a detailed zonation of the foreshore area. Different morphodynamic zones happen to be corresponding quite well to the distribution of morphological forms.

Table 2 - Proposal for a morphodynamic zonation of the shoreface of the East Frisian Islands based on statistical parameters.

Zone	Depth	Characteristic morphological forms	Turnover	In-or decrease of depth per year	Correlation coefficient r^2	Additional parameters
Foreshore	0 - -4 m NN	strand parallel flats	++	++ to --	--	?
Upper shoreface (accumulative)	-4 - -8 m NN	partly shoreface connected ridges	++	+	-	?
Lower shoreface (erosive)	-4 - -8 m NN	?	+	--	0	?
Lower shoreface	-8 - -20 m NN	partly large ridges	0	-	+	?
Flat seaground	< - 20 m NN	unstructured, flat	0	0	++	?

Typical values for these parameters have to be determined. Meaning of the symbols: ++ very large , + large, 0 almost zero, - small, -- very small.

Conclusions

With use of GIS-software more precise results from sea survey data can be obtained than those derived with conventional methods. Substantial inaccuracies in sea survey data were detected and the suitability of the data set for morphological evaluations is in question. However, the inaccuracies could be partly quantified and corrected, and incorrect use of the data was avoided. The uniform grid database turned out to be easy to manage and flexible enough to allow quality assessment which would otherwise not have proven feasible. The influence of measurement techniques on resulting depth could be determined and the calculation of statistical parameters could be conducted in a time and cost effective manner. A set of statistical parameters was calculated and represented spatially. In principle, these parameters can be calculated for areas of any size and cell resolution. In order to represent inaccuracies in sea survey data and small morphological modifications, the operations were done in small grid cells. However, the parameters used can be summarized for any larger area to improve the statistical reliability. The concept of a morphodynamic zonation of the shoreface is introduced. It is based on GIS methods and quantified statistical parameters. The results presented, the accuracy obtained, and the methods developed would not all have been possible without the use of a GIS.

Acknowledgement

This study was supported by the Bundesministerium für Bildung und Forschung in the course of the KFKI research project 'Morphological development in the shorefaces of the German Bight' (03KIS308-1A). Very special thanks to Maike Puschmann, Anne Koopmann and Dirk Hermsmeyer for their part on this work.

Bibliographic references

Hofstede J., 1991. Hydro- und Morphodynamik im Tidebereich der Deutschen Bucht. Berliner Geographische Studien, 31, 117 p.

Hüttemeyer P., Koopmann A., Kunz H., Puschmann M., 1998. KFKI Forschungsvorhaben "Morphologische Gestaltungsvorgänge im Küstenvorfeld der Deutschen Bucht", Zwischenbericht 1997. Dienstbericht Forschungsstelle Küste 6/1998, unpubl., Norderney, 22 p.

Hüttemeyer P., Koopmann A., Kunz H., Puschmann M., 1999. KFKI Forschungsvorhaben "Morphologische Gestaltungsvorgänge im Küstenvorfeld der Deutschen Bucht", Datendokumentation und Untersuchungen zur Verwendung von Seevermessungen des DHI/BSH für morphologische Fragestellungen, Abschlussbericht 1999, Dienstbericht Forschungsstelle Küste 18/1999, unpubl., Norderney, 101 p.

Stephan H.J., Ragutzki G., Abels U., Kunz H., 1998. Long-term morphological development of the Accumer Ee tidal inlet and its impact on island beaches and engineering responses. ICCE 1998, Copenhagen, paper 279.

Verwaest T., Kunz H., Hüttemeyer P, Stam J.-M., Soulsby R., Laustrup C., Toxvig Madsen H., 1999. Profile Steepening. A report prepared for the North Sea Coastal Management Group, unpubl., Lemvig, 37 p.

Application des données hydrographiques à l'étude synthétique de l'environnement côtier : exemple d'un SIG sur le littoral du Finistère (France)

Iwan Le Berre[(1)], Jean Meyrat[(2)], Yves Pastol[(2)]

(1) IUEM, laboratoire Géosystèmes, UMR 6554, place Nicolas Copernic, 29280 Plouzané, France - iwan.leberre@univ-brest.fr

(2) Shom, Section Géodésie-Géophysique, 13 rue du Chatellier, BP 426, 29275 Brest Cedex, France

Résumé

Cet article vise à présenter les résultats d'une thèse de géographie dont l'objectif était d'aboutir à une synthèse de l'environnement côtier du Finistère, notamment sous forme cartographique. Ce type d'approche nécessite la prise en compte de nombreux paramètres physiques, biologiques et socio-économiques, qui a justifié la mise en œuvre d'une base d'information géographique (BIG). Celle-ci a été structurée autour de l'information produite par le Shom qui est, en France, l'organisme responsable de l'acquisition, du traitement et de la communication de données relatives à l'environnement marin, notamment en vue d'assurer la sécurité de la navigation. Les données produites dans ce cadre concernent des paramètres fondamentaux pour l'étude de l'environnement littoral (bathymétrie, photogrammétrie, sédimentologie...). Pour les besoins de l'étude, elles ont été complétées au cours d'une recherche documentaire et de travaux sur le terrain. Les applications qui peuvent être envisagées à l'issue de ce travail sont présentées, de même que les aspects méthodologiques liés à la constitution d'un outil cohérent à partir de données de sources variées.

Abstract

This article will sum up the results acquired for a doctoral thesis in Geography. The project's aim was a synthetic study and cartography of the Finistère coastal zone (France). This sort of approach requires the study of numerous physical, biological and socio-economical parameters, that justify setting up a geographical database. The database was organized on the basis of information produced by the French hydrographic service (Shom) responsible for the acquisition, storing, processing and communication of data dealing with the marine environment, particularly for safety at sea. These data are essential for coastal zone studies. In our case, they were completed following documentary research and field

studies. Potential applications at the outcome will be described and the methodological aspects of the building of a coherent tool with data from different sources will be discussed.

Introduction

La compréhension du fonctionnement des systèmes environnementaux nécessite la prise en compte de nombreux paramètres physiques, biologiques et socio-économiques (Haines-Young *et al.*, 1993). C'est particulièrement vrai pour l'étude des systèmes littoraux, dans lesquels interagissent des milieux (marin, intertidal et terrestre) fonctionnant à des échelles spatiales et temporelles différentes (Holligan, 1994) et qui nécessitent de faire appel à des données variées et de qualité souvent hétérogène. Par les potentialités qu'ils offrent en terme d'acquisition, d'archivage, d'analyse et de restitution d'une information spatialisée multiscalaire et pluridisciplinaire, les systèmes d'information géographique (SIG) constituent des outils adaptés à une démarche synthétique en milieu côtier (Ricketts, 1992).

Le site d'étude retenu couvre la portion du littoral finistérien s'étendant entre les communes de Penmarc'h au sud et de Plouescat au nord. À terre, ses limites correspondent à celles des communes littorales, en mer elles se situent aux alentours de l'isobathe de 100 m (fig. 1). Ce site offre un échantillonnage représentatif des différents types de côte présents sous les latitudes tempérées et des problématiques de gestion et de protection qui s'y posent actuellement. Les connaissances acquises sur ce secteur, disponibles sous forme de données ou à travers la littérature, constituent un autre argument pour son choix.

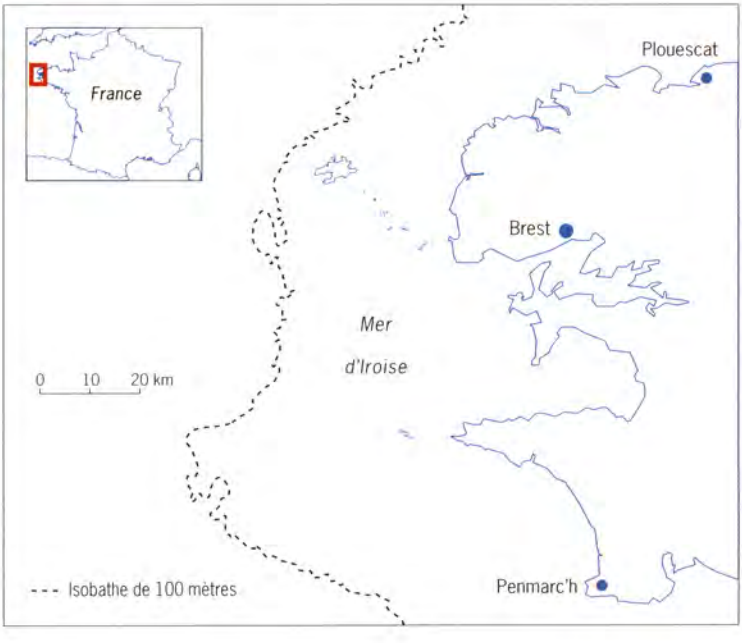


Figure 1
Délimitation de la zone d'étude.

La base d'information géographique

La base d'information géographique (BIG) élaborée pour mener à bien cette étude (Le Berre, 1999) est structurée autour de l'information produite par le Shom qui constitue la référence pour le milieu marin, partie la plus importante de la zone d'étude. Trois types d'information de référence nous ont été fournis grâce à une convention de prêt :
- la base de données bathymétriques (BDBS) qui regroupe l'ensemble des sondes numérisées à partir des minutes bathymétriques à différentes échelles, ou provenant des levés par sondeur multifaisceau ;
- l'atlas numérique des courants, calculé à partir d'une modélisation des courants liés à la marée ;
- la base de données photogrammétriques (BDBS) à 1/20 000, issue de l'exploitation des photographies aériennes de la zone intertidale.

La BIG a été complétée par le biais de conventions de prêt établies avec différents autres producteurs d'information (agence de l'Eau, institut français de l'Environnement (Ifen), institut national de la statistique et des études économiques (Insee)...), par recherche documentaire auprès des administrations compétentes (Équipement, industrie) et dans la littérature scientifique, ou encore à l'aide de données recueillies directement sur le terrain. Ces données ont été obtenues soit sous forme numérique et importées dans la base, soit numérisées à partir d'un support analogique. À l'issue de la phase d'acquisition et d'intégration des données, la BIG est composée de 35 couches d'information thématique relatives aux paramètres physiques, biologiques et socio-économiques des domaines marin, intertidal et terrestre. Sa structuration est basée sur la méthode de cartographie de synthèse mise au point par le comité MAB de l'Unesco (Journaux, 1985) et adaptée à l'information géographique. Cinq niveaux d'information, correspondant à des degrés croissants d'analyse et d'exploitation de la BIG, sont identifiés (fig. 2).

Applications

Les applications réalisées à partir de cette BIG constituent des étapes de la méthode dite de la « planification écologique », dans laquelle l'étude et la connaissance des paramètres environnementaux et socio-économiques sont traduites en terme d'aptitudes ou de contraintes pour l'usage et l'aménagement de l'espace (McHarg, 1969).

La première étape visait à produire un état de l'environnement, en particulier par la modélisation des peuplements écologiques en milieu marin. Cette information est réexploitée dans une seconde étape pour l'estimation de la valeur patrimoniale du littoral. La comparaison patrimoine-usage envisagée à l'origine de l'étude, afin de mettre en évidence les enjeux et les conflits d'intérêts actuels ou potentiels du littoral, n'a pu être menée à son terme à cause de l'absence d'information spatialisée concernant notamment les activités marines. Seule la comparaison de la valeur patrimoniale et de la protection effective de l'environnement côtier a pu être effectuée.

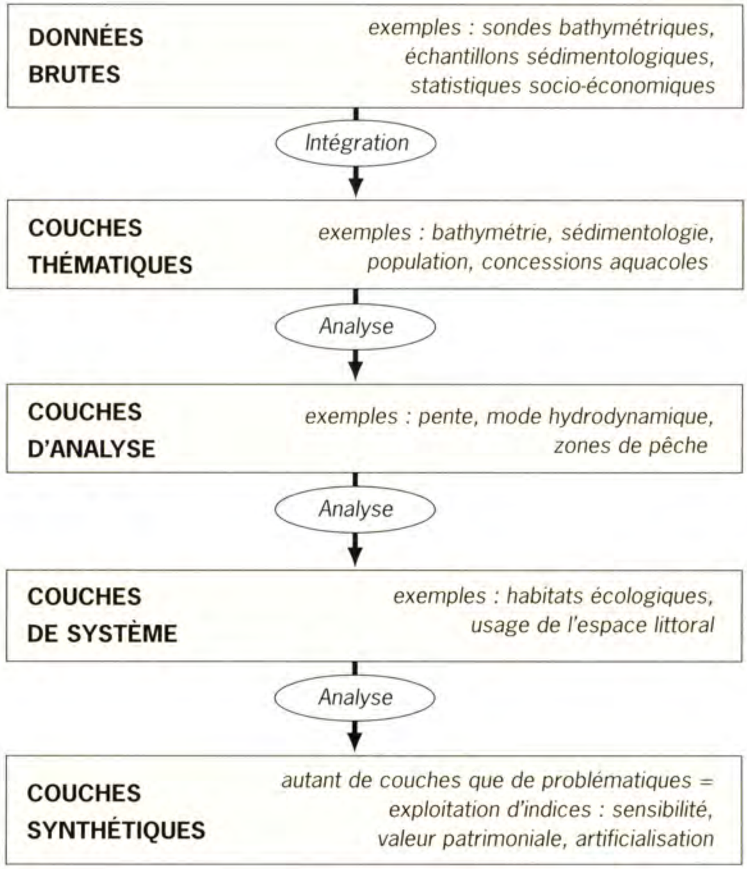


Figure 2
Structuration de la BIG (d'après Journaux, 1985).

Modélisation des peuplements écologiques en milieu marin

Au niveau local, dans un souci de simplification, il est communément admis que la répartition des peuplements animaux et végétaux en zone côtière est conditionnée par trois paramètres principaux : la profondeur, le type de substrat et le mode hydrodynamique (Floc'h, 1970 ; Chassé & Glémarec, 1976). La BIG est exploitée dans un premier temps pour la détermination de ces trois variables, puis pour leur combinaison en vue d'appliquer les modèles de répartition des peuplements écologiques mis au point par ces auteurs.

Les classes de profondeur sont calculées à l'aide d'un modèle numérique de terrain au pas de 200 m réalisé sur Arc/Info à partir de la couche bathymétrie. En zone intertidale, un modèle plus fin (au pas de 50 m) est calculé à partir des sondes bathymétriques, de courbes hypsométriques (2, 5 et 7 m) déterminées par photogrammétrie et des limites de l'estran (zéro hydrographique et trait de côte).

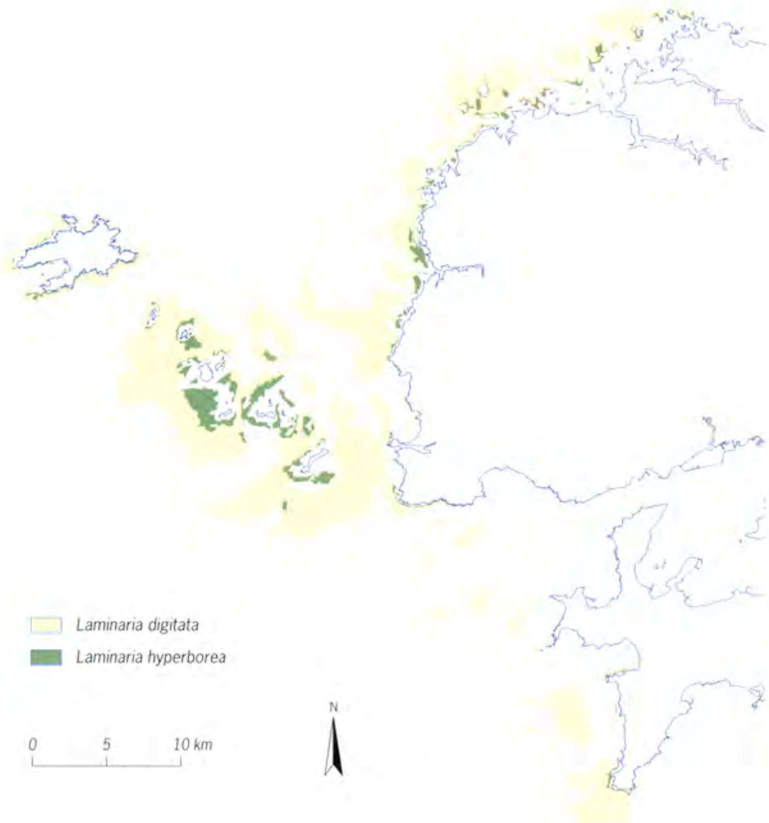
Les substrats ont été identifiés, en mer, à partir d'une couche provenant de la compilation des cartes sédimentologiques disponibles. Sur l'estran, ils sont différenciés à partir des données photogrammétriques

d'une part, qui permettent la distinction entre les substrats rocheux et sédimentaires, et d'autre part d'un échantillonnage réalisé sur le terrain, qui décrit la sédimentologie de chaque plage (Hénaff & Le Berre, 1999).
Les modes hydrodynamiques sont déduits de l'exploitation de l'atlas numérique des courants du Shom et de celle du modèle numérique de propagation des houles Swan, développé par l'université de Delft aux Pays-Bas appliqué sur le modèle numérique bathymétrique, à partir des données statistiques fournies par le service technique de la navigation maritime et des transmissions de l'équipement (STNMTE). En zone intertidale, le mode est déduit de la relation pente-granulométrie établie par le laboratoire central d'hydraulique de France (Migniot, 1982).
L'exploitation de ces paramètres environnementaux permet l'application objective des modèles de distribution de peuplements écologiques algaux en zone subtidale (Floc'h, 1970) et intertidale (Chassé, 1978), qui restent relativement simples et dont les résultats peuvent être comparés avec des cartographies existantes (Floc'h, 1970 ; Piriou, 1984). En zone intertidale les résultats obtenus apparaissent peu satisfaisants. Les données disponibles ne permettent pas d'atteindre la précision requise, en particulier dans les champs de blocs qui constituent des mosaïques complexes d'habitats. En zone subtidale, l'application du modèle de répartition des champs de laminaires (fig. 3) donne des résultats proches des estimations existantes (Arzel, 1998). Les données employées apparaissent donc mieux adaptées à une étude au niveau départemental. Toutefois, un travail plus approfondi, appuyé par une validation de terrain, devra être envisagé en collaboration avec des biologistes, afin d'affiner les paramètres de la modélisation.

Identification des sites de valeur patrimoniale

La valeur patrimoniale permet de caractériser des espèces, des milieux, des paysages ou des ouvrages, en fonction de critères de rareté, d'exposition à des risques ou de représentativité d'un caractère local ou régional (Lamotte, 1985). Cette notion est donc très relative dans l'espace et dans le temps et peut ainsi s'exprimer à différentes échelles : locale, régionale, nationale ou internationale. Dans la méthode que nous avons employée, l'estimation de la valeur patrimoniale est effectuée à partir de trois couches regroupant respectivement les habitats, les espaces et les espèces remarquables.
Les habitats considérés comme sensibles au titre de la loi Littoral ont été identifiés à partir de Corine Land Cover, corrigé et complété sur le terrain par photo-interprétation et par recherche documentaire. En domaine marin, plusieurs types d'habitats ont été distingués à partir des couches suivantes : substrats sédimentaires intertidaux, faciès biosédimentaires sous-marins, herbiers sous-marins et de l'estimation des peuplements algaux potentiels. Les inventaires environnementaux (Znieff, Zico) et les sites Natura 2000 ont en outre été retenus comme espaces remarquables, car leur choix et leur délimitation découlent d'un constat

Figure 3
Estimation de la répartition des peuplements de laminaires (partie nord de la zone d'étude).



scientifique sur le terrain. En ce qui concerne les espèces, seuls les mammifères et les oiseaux marins ont été considérés en raison de leur caractère emblématique à partir d'études publiées par Océanopolis (Liret *et al.*, 1996), et la Société pour l'étude et la protection de la nature en Bretagne (SEPNB) (Cadiou, 1998).

Ces différentes couches ont ensuite été superposées, sans pondération, en vue de fournir une indication de la valeur patrimoniale du littoral de la zone d'étude (fig. 4). La forte valeur des systèmes insulaires et de leurs abords, mise en évidence par cette méthode, apparaît fortement liée à leur fréquentation par les mammifères marins. À une échelle plus grande, la prise en compte d'un nombre d'éléments plus important, et notamment de l'ensemble des stations d'espèces rares ou menacées, permettrait certainement d'aboutir à une estimation plus fine de la valeur patrimoniale. Mais elle ne pouvait être envisagée sur l'ensemble de la zone d'étude. De plus, en milieu marin, le choix des espèces remarquables ne fait pas l'unanimité. L'approche par habitat apparaît donc plus pertinente, mais leur inventaire est loin d'être exhaustif.

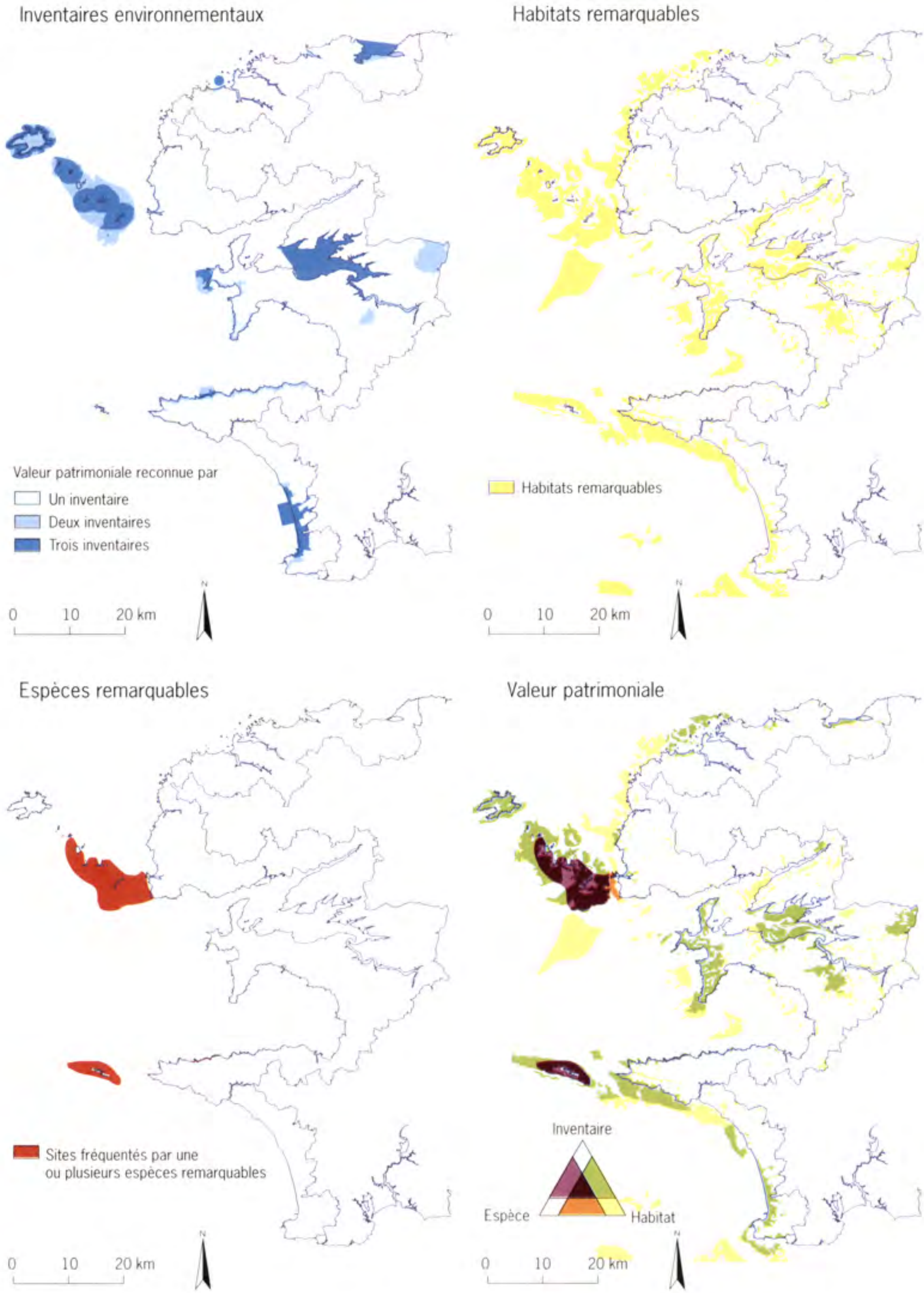


Figure 4 - Méthode d'estimation de la valeur patrimoniale.

La protection du patrimoine environnemental

La comparaison par superposition de la valeur patrimoniale ainsi définie et des mesures de protection de l'environnement, montre la faible protection générale dont bénéficie le milieu marin (fig. 5). De plus, une partie importante de ces protections provient du classement du domaine public maritime, qui ne concerne que le fond de la mer et non la colonne d'eau. Il s'agit de l'application en milieu marin d'une juridiction définie pour le domaine terrestre et donc peu adaptée à sa réglementation. La mise en place du programme Natura 2000 et celle d'un parc national marin pourraient constituer l'occasion de repenser les modes de protection de l'environnement marin ou tout au moins offrir le cadre et les moyens nécessaires à l'amélioration de la connaissance du patrimoine environnemental et, plus largement des systèmes écologiques littoraux, ainsi qu'à celle de l'usage et de l'exploitation qui en est faite.

Discussion

L'information numérique disponible sur le littoral finistérien ne permet pas la constitution d'un outil suffisamment homogène et complet pour envisager une synthèse de l'environnement. Ce constat est fondé sur les éléments suivants :

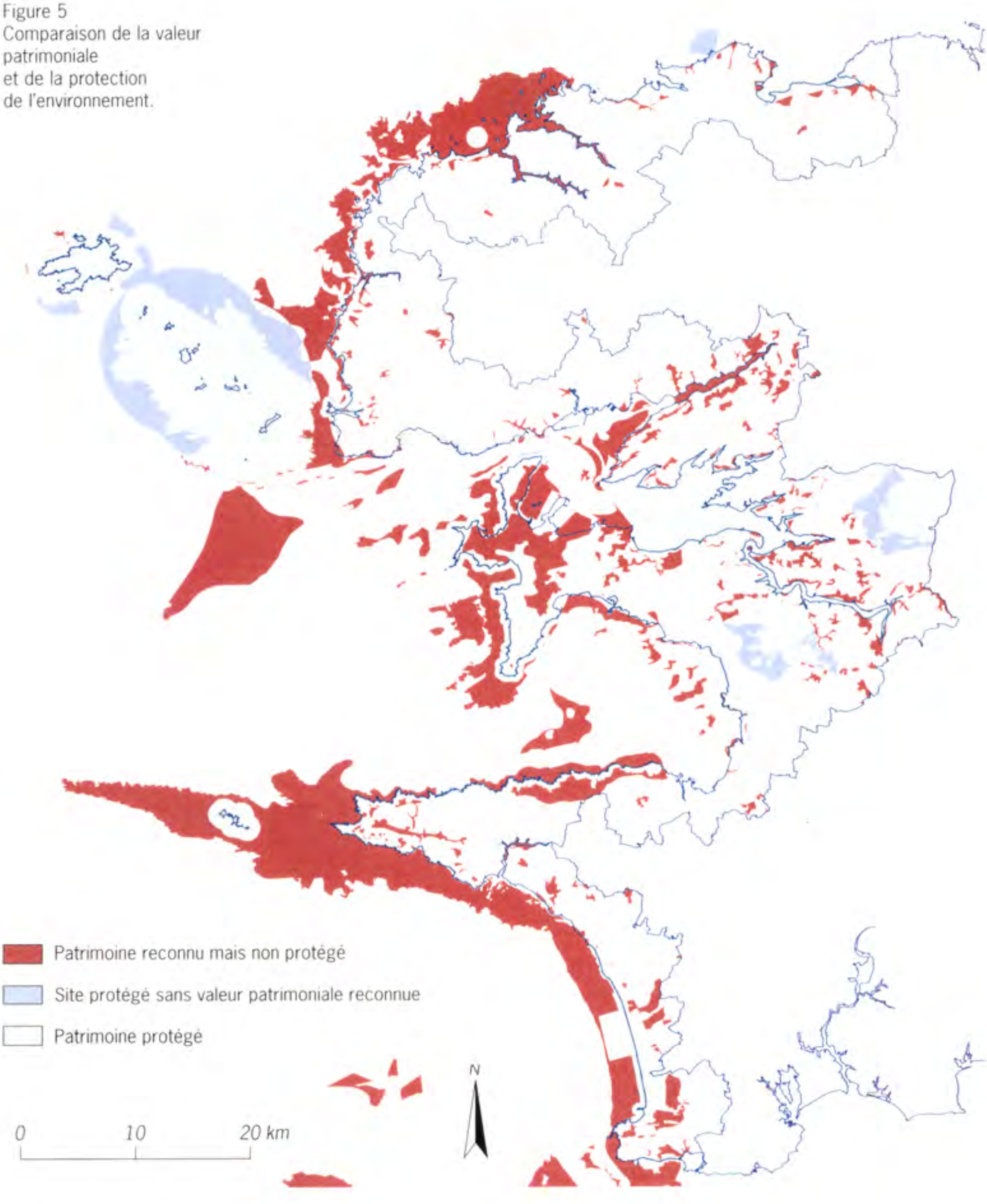
• L'information de référence pour le milieu marin est produite par le Shom dont les produits numériques (bathymétrie, sédimentologie, photogrammétrie...) sont pour la plupart en cours d'élaboration. De ce fait, une participation active à l'effort d'intégration des données (minutes bathymétriques) s'est avérée indispensable pour pouvoir bénéficier de l'information dans le cadre de cette étude. Sur le milieu terrestre, l'information de référence n'a pu être obtenue auprès de l'IGN en raison de son coût élevé. Si l'utilisation des produits dérivés de l'IGN (BD Carthage) a permis de contourner ce déficit, c'est au détriment de la précision de l'information puisqu'elle n'est analysable qu'à 1/50 000 ;

• Les bases d'information produites à l'échelle européenne, dans le cadre du programme Corine, peuvent être obtenues aisément auprès de l'Ifen, mais elles s'avèrent décevantes à l'usage en raison de divers problèmes de qualité (précisions géométrique et typologique, erreurs, absence d'homogénéité).

Compte tenu du caractère incomplet de l'information numérique disponible sur certains thèmes, la base d'information géographique a fait l'objet d'un enrichissement fondé sur la recherche documentaire, sur des requêtes adressées aux administrations compétentes sur le littoral et sur la collecte de données sur le terrain. Ce rassemblement de données de nature hétérogène a impliqué un travail de mise en cohérence géométrique et sémantique extrêmement long, mais indispensable. À l'issue de la phase d'intégration des données, la première constatation reste attachée à la qualité variable de l'information numérique résultante.

• L'exhaustivité de l'information est déficitaire en domaine marin. Malgré la couverture d'une partie importante de la zone étudiée, il existe

Figure 5
Comparaison de la valeur patrimoniale et de la protection de l'environnement.



certaines zones non levées en bathymétrie et en sédimentologie. La côte nord apparaît particulièrement défavorisée à cet égard. Les habitats remarquables et les sites clés de l'écosystème marin sont relativement mal identifiés en raison du retard des inventaires Znieff en milieu marin par rapport à leurs équivalents terrestres. De même, on ne dispose ainsi que de très peu d'information spatialisée concernant l'usage du milieu marin et la fréquentation des estrans.

• De nombreuses données sont anciennes, telles que les données bathymétriques du XIX[e] siècle de l'archipel de Molène ou les données sédimentologiques sous-marines qui datent pour la plupart des années soixante. Ainsi, les documents les plus récents établis par le Shom sont réalisés à partir de ces mêmes échantillons, voire à partir des données recueillies par la méthode du plomb suiffé, antérieures à 1940, et ne fournissant qu'une description imprécise de la nature des fonds. L'âge des données peut poser un problème d'actualité et donc de cohérence des résultats. C'est particulièrement vrai dans le domaine marin, soumis à des variations cycliques à différentes échelles temporelles (biquotidiennes, mensuelles, saisonnières...) pouvant être modifiées durablement à l'occasion d'événements climatiques (ouragan de 1987), ou anthropiques exceptionnels (marée noire de l'*Amoco Cadiz*).
• Les différences d'échelles spatiales et temporelles peuvent poser le problème de la compatibilité des informations produites sur les différents domaines. L'apport de la démarche de cartographie de synthèse peut être important à cet égard par la définition d'indices tels que la valeur patrimoniale ou l'artificialisation. En tout état de cause, la compatibilité de l'information n'est pas immédiate car les limites physiographiques (zéros et trait de côte notamment) sont différentes entre le Shom et l'IGN (Le Gouic, 1999).

Perspectives

L'approche engagée dans une perspective de typologie et de représentation synthétique de l'environnement littoral nécessite des avancées à deux points de vue :
- au point de vue des connaissances, par l'amélioration de l'information spatialisée, concernant en particulier le milieu marin, tant des points de vue écologique que socio-économique (usage de l'espace). L'apport des SIG est évident dans ce domaine grâce à leur capacité à constituer un support d'archivage et d'analyse de données différentes (thème, échelle) provenant de sources variées (terrain, télédétection), et par les potentialités offertes en terme d'analyse qualitative et quantitative de l'information, et notamment par la possibilité de couplage avec des modèles spatio-temporels. En retour, l'information intégrée à la BIG peut fournir une base de connaissance pour la définition des stratégies d'échantillonnage, pour l'exploitation de l'information et pour la validation des modèles ;
- au point de vue méthodologique, une réflexion doit être menée concernant la combinaison de l'information telle qu'elle est conçue dans la planification écologique en vue d'appréhender la complexité de systèmes littoraux d'échelles variées et fonctionnant à différents pas de temps. L'exploitation des indices utilisés en écologie (artificialisation, sensibilité, dégradation...) et la mise au point de nouveaux indices ouvrent des perspectives intéressantes à ce niveau. Pour cela, des avancées significatives peuvent également être attendues du couplage SIG-modèles dynamiques.

L'intégration de l'ensemble des données spatialisées disponibles sur la frange littorale finistérienne est en grande partie achevée. Bien que des lacunes subsistent, l'outil constitue néanmoins une plate-forme suffisamment développée et structurée pour faciliter l'intégration de données complémentaires afin de répondre à des applications déterminées. Évidemment, ces perspectives ne peuvent s'envisager que si le SIG, support de la BIG, est pérennisé ; ceci nécessite un support institutionnel, l'élaboration de conventions avec les producteurs de données ainsi que la collaboration active des thématiciens de l'environnement.

Références bibliographiques

Arzel P., 1998. Les laminaires sur les côtes bretonnes : évolution de l'exploitation et de la flottille de pêche, état actuel et perspectives. Éd. Ifremer, 139 p.

Cadiou B., 1998. Oiseaux marins nicheurs de Bretagne, 1995-1998. Bretagne Vivante, SEPNB, Conseil régional de Bretagne, Diren Bretagne (eds).

Chassé C., Glémarec M., 1976. Principes généraux de la classification des fonds pour la cartographie biosédimentaire. J. Rech. Océanogr., 1(3).

Chassé C., 1978. Production primaire benthique en milieu rocheux. *In:* Synthèse des études écologiques d'avant-projet des sites bretons de Beg an Fry, Ploumoguer, Plogoff, Saint-Vio et Erdeven. Rapp. Sci. Techn., Cnexo, 38, 58 p.

Floc'h J.-Y., 1970. Cartographie de la végétation marine dans l'archipel de Molène (Finistère). Rev. Trav. ISTPM, 34(1), 89-120.

Haines-Young R., Green D.R., Cousins S.H. (eds), 1993. Landscape ecology and GIS. Taylor & Francis, London, 288 p.

Hénaff A., Le Berre I., 1999. Sedimentary dynamic and artificialisation of shores: methodology and preliminary results of a GIS applied to the west coast of Brittany (France). J. Coast. Res., (soumis).

Holligan P.M., 1994. Land Ocean Interaction In the Coastal Zone (LOICZ): Implementation plan. Science plan., IGBP, 215 p.

Journaux A. (éd.), 1985. Cartographie intégrée de l'environnement. Un outil pour la recherche et pour l'aménagement. Notes techniques du MAB-Unesco, Union Géogr. Int., 55 p. + 10 cartes.

Lamotte M. (éd.), 1985. Fondements rationnels de l'aménagement d'un territoire. Coll. Écologie appliquée et sciences de l'environnement. Masson, Paris, 175 p.

Le Berre I., 1999. Mise au point de méthodes d'analyse et de représentation des interactions complexes en milieu littoral. Thèse de doctorat de géographie, université de Bretagne occidentale, Brest, 230 p.

Le Gouic M., 1999. Informations géographiques et références associées. *In:* CoastGIS'99, Brest, sept. 1999, Éd. Ifremer, Actes Colloq., 25, 11-17.

Liret C., Creton P., Le Moal G., Ridoux V., 1996. Dolphin home range and reserve zonation: do we need field studies to define management policy? Eur. Res. Cetaceans, 10, 15-19.

McHarg I.L., 1969. Design with nature. The Natural History Press, 183 p.

Migniot C., 1982. Étude de la dynamique sédimentaire marine, fluviale et estuarine. Thèse d'État de sciences naturelles, université de Paris-Sud, 109 p.

Piriou J.-Y., Chapron V., Dreves L., Youenou G., 1984. Carte de la végétation marine côtière : secteur aber Wrac'h, aber Benoit. Ifremer Brest, Dero/el, 1/20 000.

Ricketts P.J., 1992. Current approaches in GIS for coastal management. Mar. Pollut. Bull., 25(1-4), 82-87.

Spatial analysis of soil erosion *versus* sediment yields: an assessment of riverine sediment discharge to the coastal zone. Case study of the Bay of Biscay watersheds

Éric Maneux[(1)], Wolfgang Ludwig[(2)], Jean-Luc Probst[(3)], Henri Etcheber[(1)]

(1) Université de Bordeaux I, DGO-UMR CNRS 5805, av. des Facultés, 33405 Talence Cedex, France maneux@geocean.u-bordeaux.fr

(2) Université de Perpignan, centre de formation et de recherche sur l'environnement marin (Cefrem), av. de Villeneuve, 66100 Perpignan Cedex, France

(3) Université Paul Sabatier, laboratoire des mécanismes des transferts en géologie (LMTG), route de Narbonne, 31062 Toulouse Cedex, France

Abstract

In order to assess riverine sediment inputs to the coastal zone of the southern part of the Bay of Biscay, sediment yields of 50 river stations of the Gironde and Adour watersheds were estimated using suspended matter field measurements.
Concurrently, a watershed information system was updated in order to assess the soil erosion risks in the region studied. An erosion index (I_{ero}) was estimated for each watershed from the soil erosion risk map. The I_{ero} were correlated with sediment yields, allowing us to propose an empirical model for riverine sediment flux to the coastal zone. Using an empirical model based on geographical databases provided an assessment of sediment flux for poorly documented rivers, especially small coastal rivers.

Résumé

Afin d'évaluer les apports de sédiments aux zones côtières du sud du golfe de Gascogne, les flux de matières en suspensions (MES) et les transports spécifiques des rivières ont été mesurés en une cinquantaine de sites des bassins versants de l'Adour et de la Gironde.
Parallèlement, la constitution d'un SIG a permis de décrire le risque d'érosion dans les bassins versants étudiés. Un indice (I_{ero}) du potentiel d'érosion de chaque bassin est calculé à l'aide de la cartographie du risque d'érosion. Les corrélations observées entre I_{ero} et les transports spécifiques mesurés permettent de proposer un modèle empirique d'estimation des flux de MES. Ce type d'approche nous a conduits à établir un bilan de matière régional qui tient compte notamment des petits fleuves côtiers peu documentés jusque là.

Introduction

It is well known that inputs of matter to the ocean surface come from three main sources: atmospheric inputs, continental freshwater inputs and deep water upwelling. For instance, in the southern part of the Bay of Biscay, geochemical inputs from the atmosphere are as high as those from rivers (Maneux *et al.*, 1999a). However, most studies try to assess sediment and geochemical fluxes to the coastal zones (CZ) carried by rivers (Meybeck & Ragu, 1996). These studies are important in understanding the biogeochemical and sedimentological processes which occur in lagoons, estuaries and coastal margins. For example, riverine organic matter entering estuaries is rapidly mineralised, as shown in the Gironde estuary (Abril *et al.*, 1999). Moreover, a great part of the human population lives near the coast in close relationship with its natural resources which can be endangered by anthropogenic pollution and activities (Pernetta & Milliman, 1995). In the case of the Gironde estuary, water and sediments are contaminated with cadmium which is primarily adsorbed on riverine particles (Lapaquellerie *et al.*, 1995).
Thus, the first significant assessment is to determine the total suspended matter (TSM) flux to the CZ by rivers. Many authors have already estimated the river sediment budget to the ocean on different time and spatial scales. Firstly, field data were extrapolated or compiled (Milliman & Meade, 1983). Concurrently, geomorphologists, agronomists and hydrologists developed empirical or physically-based models of soil erosion and TSM fluxes from watersheds (Wishmeier *et al.*, 1958; Ahnert, 1970; Pinet & Souriau, 1988; De Roo *et al.*, 1994). More recently, as a result of studies on climate change and biogeochemical cycles, empirical models have been proposed to correlate river sediment fluxes (Milliman & Syvitski, 1992) with simple environmental watershed features. The latest improvement is the use of global spatial databases (Ludwig & Probst, 1996, 1998).
Now, availability of environmental databases and progress in remote sensing techniques make it possible to assess the soil erosion risk and river TSM fluxes from watersheds on a regional scale. Thus, for the southern part of the Bay of Biscay, these risks and fluxes were studied in the Gironde and Adour watersheds on different time and spatial scales (De Maisonneuve *et al.*, 1997; Maneux, 1998). The aim of this paper is to describe the different methods applied. The significance of these empirical models as well as the interest of the available databases will be discussed.

Sites and methods

A network of 50 schools, the Classes-EcoFleuves was managed for river monitoring from 1994 to 1997.This program was part of the GIS Eco-BAG research program supported by the Aquitaine and Midi-Pyrénées regions, and by the agence de l'Eau Adour-Garonne water board.

Water samples were taken by teachers and pupils, which allowed us to estimate TSM fluxes and particulate organic carbon fluxes for about 50 sub-watersheds of 200 km^2 up to 53 000 square kilometres. Specific sediment yields ($t.km^{-2}.yr^{-1}$) ranged from 3 $t.km^{-2}.yr^{-1}$, downstream from the big dams on the Dordogne river, up to 120 $t.km^{-2}.yr^{-1}$ for the Tarn river (Maneux, 1998) (fig. 1).

In order to explain the observed distribution of specific sediment yields, spatial analysis of soil erosion risk and TSM storage capacities in the river catchments were performed with a GIS. The European Corine Land Cover database was used to describe land use and cover in only two types of areas: protected or unprotected by vegetation. The Soil Geographical Database for Europe (SGDBE), was used to assess textural and lithological soil features. A digital chart of a soil erodibility index derived from these features was kindly provided by the service de science du sol, of the Inra research institute. Thirty year-averaged monthly precipitations were available from the BD CLIM of Météo-France for 120 stations in the study area and allowed us to evaluate the rainfall erosivity (annual precipitation and Fournier index).

$$\text{Fournier index} = \sum_{i}^{12}(P_i^2 / \overline{P}) \qquad \textit{Pi: mean monthly precipitation}$$

A Digital Elevation Model (VISUAL DEM) for France was used for geomorphological analysis and determining drainage basin areas. The European Lakes, Dams and Reservoirs Database (ELDRED) was used for dam description (water volume, averaged annual run off, natural drainage area, etc.). Spatial analyses were performed with Arc/Info and IDRISI software.

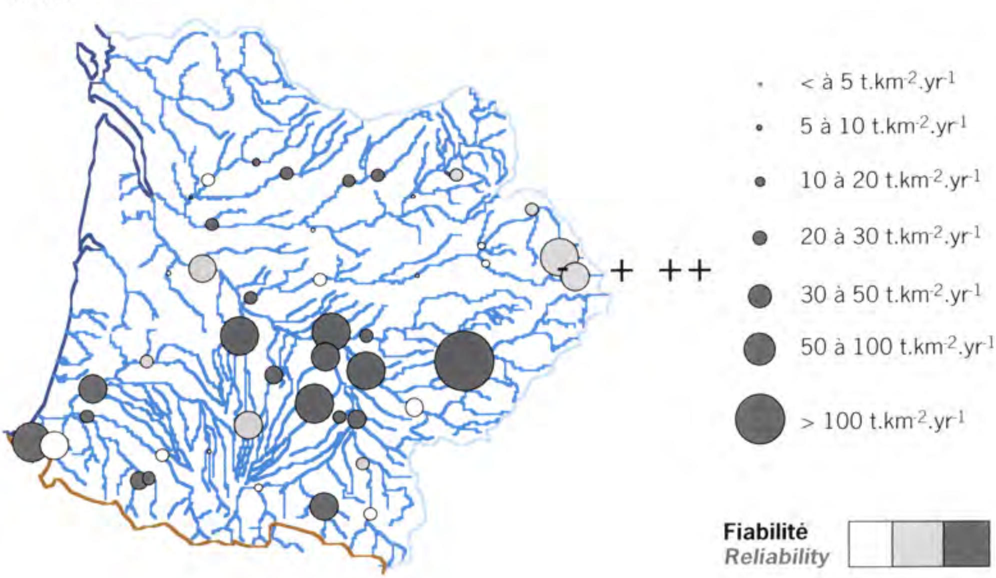


Figure 1
Specific sediment yields in the Adour, Dordogne and Garonne watersheds estimated at gauge stations of the Classes-Ecofleuves network.

Dam trapping efficiency

Dam trapping efficiency (TE), which is the percentage of the natural suspended sediment flux trapped in the reservoir, can be estimated using the hydraulic residence time (Vörösmarty *et al.*, 1997). On a regional scale, the impact of several dams can be assessed by taking into account the spatial organization of dams along the river network. A method to estimate the global trapping efficiency (TEw), for any watershed containing more than one dam has been proposed (Maneux, 1998; Maneux *et al.*, submitted). Thus, TEw may respectively reach 40% and 70% in the lower reaches of the Dordogne and Lot rivers.

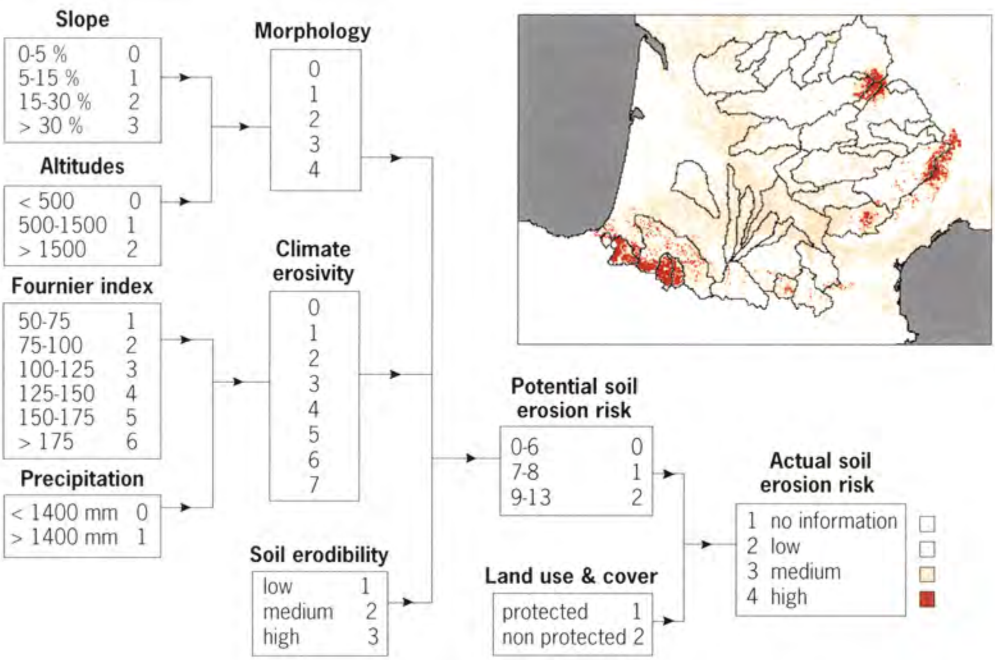
Positive correlation between drainage areas and river sediment loads corrected for dam retention, as well as comparisons between TEw-corrected sediment yields and sediment yields measured up stream from the dams, highlight the interest of the method in reconstituting natural sediment yields. This correction let us estimate the impact of river regulation on river transport capacity. Corrected sediment yields can then be compared with the spatial analysis of soil erosion risk.

Soil erosion risk assessment

The databases and the spatial analysis of their relationships allowed us to determine a soil erosion risk index for the watersheds investigated. All the information was aggregated on the 525 m x 525 m grid size of the available Digital Elevation Model (DEM).

First, each feature was correlated with the sediment yields in order to determine the significant parameters in regional erosion and transport processes. We also tested parameter products but no significant correlation

Figure 2
Soil erosion risk assessment methodology.



was found. We then applied the soil erosion assessment methodology (reclassing and overlay) already used by Corine (1992) to our databases. Finally, four classes of soil erosion risk were determined; the spatial information is presented within the basin limits in figure 2.

In order to integrate spatial information at the watershed level, we propose to use an index which takes the surface ratio between different soil erosion classes into account. Thus, the soil erosion index, I_{ero}, for a watershed was determined as follows:

$$I_{ero} = \frac{\text{area (risk} \geq 2)}{\text{total area}} + \frac{\text{area (risk} \geq 2)}{\text{total area}}$$

I_{ero} seems to be correlated with sediment yields, but it can be seen in figure 3 that the Tarn watershed points are clearly outside of the main cluster. These points were not used for correlation coefficient calculation. This can be explained by the high sediment yields recorded in the Tarn watershed due to a 50 year-flood observed for the studied period as well as by the soil erosion risk assessment methodology which may not be able to take into account some climatic changes in the upper reaches of the Tarn river (Mediterranean climate).

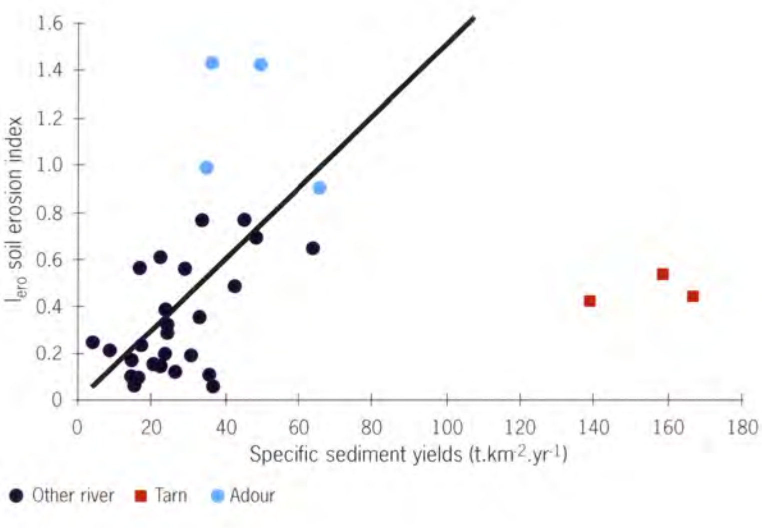


Figure 3
Soil erosion index, I_{ero}, *versus* specific sediment yield; points of the Tarn watershed were not used for correlation coefficient calculation.

Discussion

The first data used in studies on TSM transport by rivers are annual river water discharge and TSM fluxes (or sediment yields) measured at gauging stations. On the global scale, such information comes from a compilation of bibliographical data. This is heterogeneous information which may present huge differences in data quality and no temporal correlation (Milliman & Syvitski, 1992 ; Ludwig & Probst, 1996, 1998).

Most of the time, only mean annual values are available and sampling conditions and frequencies are not well known. The reliability of such data is not easy to determine. On our regional scale, the program Classes Ecofleuves was a TSM survey which provided several data series on TSM fluxes and water discharge spanning the same period. Clearly, the values statistical significance could be calculated, but it was also important to estimate the quality of the TSM flux estimations from metadata and from the coefficient of TSM-Q regressions (Maneux, 1998) for each calculated sediment yield value in order to determine which data sets were significant for the period studied. Indeed, only 30 sediment yields out of 50 monitored gauging stations were selected. The main difficulty is to get reliable TSM fluxes from drainage basins with surface areas under 2000 square kilometres. Nevertheless, on smaller scales, such as the Nivelle river watershed (165 km^2), the spatial correlation can be performed with point TSM concentrations recorded along the stream during flood events (De Maisonneuve *et al.*, 1997). The reliability of such TSM data is good but the spatial and temporal significance is not well known.

In the same way as the Universal Soil Loss Equation (Wishmeier *et al.*, 1958) and the global sediment flux modeling of Ludwig & Probst (1996, 1998), morphological (slope, altitude), climatological (Fournier index), soil erodibility (texture, lithology) and Land Use and land Cover databases (LUC) were gathered in a GIS in order to describe each watershed (Band, 1989; Corine, 1992). On the regional scale, the spatial resolution seems sufficient to describe the watershed features. The minimum spatial integration unit per watershed seems to be statistically significant. Indeed, the smallest watershed (165 km^2) could be described by 660 pixels, whereas only five pixels were used to describe a 9 000 km^2 watershed on a global scale.

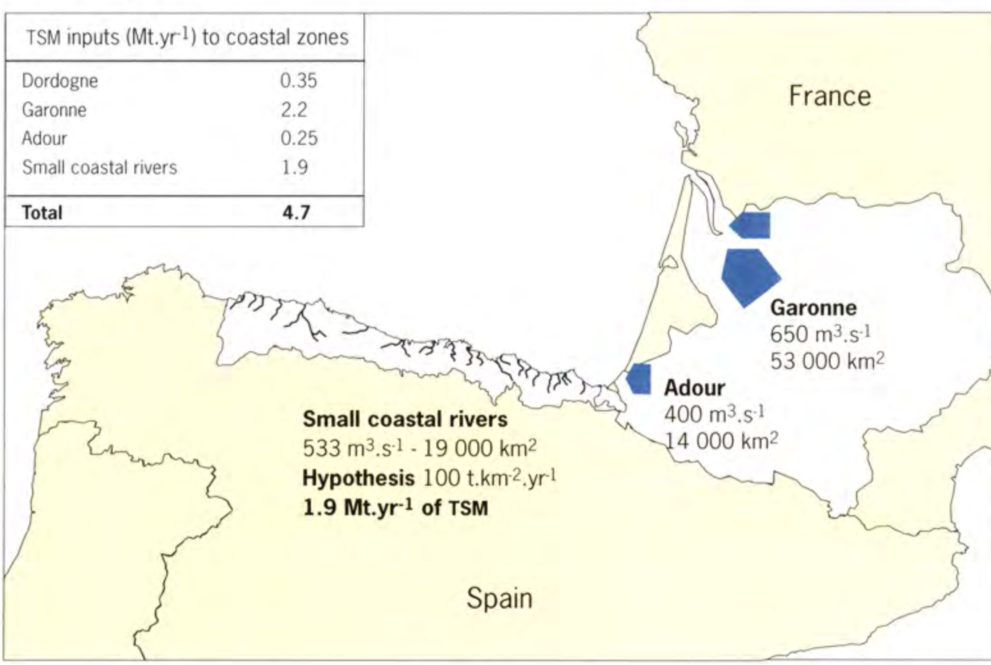
On the global scale, significant correlations were further determined between observed sediment yields and the different environmental features for a set of 60 rivers (Ludwig & Probst, 1996, 1998). The range of sediment yields (4 - 2 500 $t.km^{-2}.yr^{-1}$) and the different types of watersheds (from Arctic to Himalayan) make it possible to determine the significant features for different climatic zones. For the Bay of Biscay, the best empirical model is that of a temperate wet climate:

Sediment yield = 000.83 (slope. Fournier index).

Similar relationships were not determined on a regional scale, since no significant correlation between sediment yields and basin features were found. This is probably due to a shorter sediment yield range: from 5 to 150 $t.km^{-2}.yr^{-1}$. Moreover, the watershed features still differed significantly especially between the smallest watersheds, but sediment yield reliability decreases with basin size. Thus, spatial resolution of the available databases is probably not the limiting factor.

On the other hand, environmental information for the South-West of France in available databases is limited. For example, LUC was described with the Corine Land Cover database which contains 44 classes, but with respect to soil erosion, only two classes are significant: permanent vegetation and non permanent vegetation. Furthermore, as for the climatic data set, the information used was the 30-year-mean monthly precipitation, whereas our study took place in 1995, 1996 and 1997. Nevertheless, the actual soil loss assessment methodology (Corine, 1992; Maneux, 1998) allowed us to determine a soil erosion index, I_{ero} for each watershed, which seems to be correlated with sediment yields. The TSM export from the watershed also depends on the sediment transport capacity of rivers. One important process is the retention of sediments in the lower reaches of the watershed, such as wetlands and flood plains. Until now, we have not been able to assess this process but we have assessed the impact of anthropogenic sedimentation (Maneux *et al.*, submitted). In fact, our information system integrated the ELDRED database. According to the empirical relationship between water residence time and dams trapping efficiency (TE) (Vörösmarty *et al.*, 1997), we have been able to determine TE and the global watershed trapping efficiency (TEw). This is important, as we can reconstitute natural sediment yields. The usefulness of overlaying a stream river network (digitized or extracted from DEMs) with a dam database can be highlighted.

In conclusion, the global approach makes it possible to estimate sediment yields and also sediment fluxes to the CZ. Indeed, the estimation of sediment yields from the Cantabrian and Basque coast, determined with the global empirical model, are in the range of 50 - 500 $t.km^{-2}.yr^{-1}$ whereas the reliable field measurements for the Nivelle river are about



TSM inputs ($Mt.yr^{-1}$) to coastal zones	
Dordogne	0.35
Garonne	2.2
Adour	0.25
Small coastal rivers	1.9
Total	**4.7**

Figure 4
Riverine TSM inputs to the coastal zone of the South Bay of Biscay.

75 t.km^{-2}.yr^{-1} (Maneux *et al.*, 1999b). Nevertheless, as the regional model shows that there is no significant correlation between sediment yields and other parameters, such empirical models must be used with precaution.

However, at the regional level, the empirical model using the Soil Erosion Index, I_{ero}, can estimate specific sediment yields and mean inter-annual TSM fluxes to the CZ quite reliably in basin areas exceeding 2 500 km^2. For now, just as the TSM flux databases are not precise enough, the spatial databases available to develop such empirical models are not representative enough. Thus, in future, we will have to improve the temporal representativeness of climatic and LUC databases (integrating seasonal variations) and to improve the thematic descriptions of LUC and soil classes.

In spite of these facts, the study allowed us to assess the contribution of river sediment discharge to the Bay of Biscay. TSM river flux measurements and extrapolation from environmental databases, according to our empirical model, make it possible to estimate TSM river fluxes to CZ, even when no TSM data were available (fig. 4).

Small mountainous rivers (19 000 km^2) contribute to 1.9 Mt.yr^{-1}, *i.e.* 40% of the total sediment input (4.7 Mt.yr^{-1}) to the CZ in the southern part of the Bay of Biscay. Moreover, while the Garonne river has a larger contributive area (53 000 km^2), its suspended sediment input into the ocean is only 47% (2.2 Mt.yr^{-1}) of the total flux. Therefore, we emphasize the importance of small mountainous rivers for sedimentological and biogeochemical budget assessment in CZ.

Conclusions

On two different basin scales, the GIS approach and spatial analysis of the soil erosion risk make it possible to develop empirical models for river sediment yields. On a global scale, with a wide range of observed sediment yield values, this method allows us to determine the most significant controlling parameters. On a regional scale, the range of values, both for sediment yields and basin features, are too small to determine the significant parameters.

The representativeness of available databases had to be improved, but the main problem is that the sediment yield reliability decreases when the homogeneity of watershed features (such as LUC) increases. Thus, we propose that in future studies, if the main objective remains the study of the main watersheds, a reliable sediment yield assessment should also be made for small representative watersheds with drainage areas around 1 000 square kilometres.

Finally, this study allowed us to extrapolate an average value of 100 t.km^{-2}.yr^{-1} for the Cantabrian (Spain) and Basque coasts (19 000 km^2). This extrapolation highlights the fact that small coastal rivers are the first source (52%) of TSM inputs to these coastal zones. Thus, although the Garonne river is a major source of TSM to these coastal zones (42%), the Pyrenean and Cantabrian small mountainous rivers must also be taken into account in order to assess continental inputs to the Bay of Biscay. Generally, they contribute to the sedimentological and biogeochemical balance in coastal zones and continental margins.

Watershed, grid size and environmental databases features.

		This work	Ludwig & Probst, 1996, 1998
Spatial Integration Unit (SIU)		Pixels	Pixels
Grid cell size		525 m x 525 m	0.5° x 0.5°
Number of watersheds		37	50
Minimum basin area (km^2)		165	9000
Maximum basin area (km^2)		53000	5.9 10^6
Minimum SIU per watershed		660	5
Maximum SIU per watershed		212000	1393
DEM	source or name	Visual DEM	FNOC Mean modal elevation (Unesco)
	resolution	525 m x 525 m	5' x 5'
LUC	source or name	Corine Land Cover	Olson vegetation map (CDIAC)
	resolution	25 ha	0.5° x 0.5°
	numbers of LUC classes	44	
Precipitation	source or name	BD-CLIM (Météo-France)	digitalisation and rasterisation of maps (Unesco)
	resolution	5.5 km x 5.5 km	0.5° x 0.5°
Soil and Lithology	source or name	SGDBE (Inra)	CGS global dataset CD-ROM (Webb *et al.*, 1992)
	resolution	1/1 000000	1° x 1°

Bibliographic references

Abril G., Etcheber A., Le Hir P., Bassoulet P., Boutier B., Frankignoulle M., 1999. Oxic-anoxic oscillations and organic-carbon mineralization in an estuarine maximum turbidity zone (The Gironde, France). Limnol., (in press).

Ahnert F., 1970. Functional relationships between denudation, relief and uplift in large mid-latitude drainage basins. Amer. J. Sci., 268, 243-263.

Band L.E., 1989. A terrain-based watershed information system, hydrological. Processes, 3, 151-162.

Corine, 1992. Soil erosion risk in the southern regions of the European communities. Office for official publications of the EC, EUR 13233EN, 97 p.

De Maisonneuve L., Clément O., Maneux E, 1997. Évaluation des risques de colmatage du lit mineur d'une rivière dans l'optique de gestion des ressources aquatiques vivantes. *In*: Les bassins versants expérimentaux de Draix. Laboratoire d'étude de l'érosion en montagne, Éd. Cemagref, 211-221.

De Roo A.P.J., Wesseling C.G., Cremers N.H.D.T., Offermans R.J.E., 1994. LISEM: a physically-based hydrological and soil erosion model incorporated in GIS. Proc. EGIS, 94, 207-215.

Lapaquellerie Y., Jouanneau J.M., Maillet N., Latouche C., 1995. Pollution en cadmium dans les sédiments du Lot (France) et calcul de stock de polluant. Environ. Technol., 16, 1145-1154.

Ludwig W., Probst J.L., 1996. A global modelling of the climatic morphological and lithological control of river sediment discharges to the oceans. IAHS publ., 236, 21-28.

Ludwig W., Probst J.-L., 1998. River sediment discharge to the oceans: present-day controls and global budgets. Amer. J. Sci., 298, 265-295.

Maneux E., 1998. Érosion mécanique des sols et transports fluviaux de matière en suspension : Application des SIG aux bassins versants de l'Adour, de la Dordogne et de la Garonne. Thèse de l'université Bordeaux I, 1898, 250 p.

Maneux E., Grousset F.E., Buat-Ménard P., Lavaux G., Rimmelin P., Lapaquellerie Y., 1999a. Temporal pattern of the wet deposition of Zn, Cu, Ni, Cd and Pb: the Arcachon lagoon. Soil Water Air Poll., 114(1-2), 95-120.

Maneux E, Dumas J., Clément O., Etcheber H., Charritton X., Etchart J., Veyssy E., Rimmelin P., 1999b. Assessment of suspended matter input into the oceans by small mountainous coastal rivers: the case of the Bay of Biscay. C. R. Acad. Sci., Paris, 329, 413-420.

Maneux E., Etcheber H., Veyssy E., Probst J.-L. Assessment of dam trapping efficiency from water residence time: application to fluvial sediment transport in the Adour, Dordogne and Garonne river basins (France). Water Resour. Res.

Meybeck M., Ragu A., 1996. River discharges to the oceans: assessment of suspended solids, major ions and nutrients. Draft report: Global river input. GEMS/Water programme of Unep-WHO-Unesco-WMO.

Milliman J.D., Meade R.H., 1983. World-wide delivery of river sediment to the oceans. J. Geol., 91, 1-21.

Milliman J.D., Syvitski J.P.M., 1992. Geomorphic/tectonic control of sediment discharge to the ocean: the importance of small mountainous rivers. J. Geol., 100, 525-544.

Pernetta J.C., Milliman J.D., 1995. Land-ocean interactions in the coastal zone, LOICZ implementation plan. Global change IGBP rep., 33, 43-50.

Pinet P., Souriau M., 1988. Continental erosion and large scale relief. Tectonics, 7, 563-582.

Vörösmarty C.J., Meybeck M., Fekete B., Sharma K., 1997. The potential impact of neo-castorization on sediment transport by the global network of rivers. IAHS publ., 245, 261-273.

Wischmeier W.H., Smith D.D., Uhland R.E., 1958. Evaluation of factors in the soil loss equation. Agr. Eng., 458-462.

Typologie dynamique de la zone intertidale de l'archipel des Bijagos (Guinée-Bissau)

G. Pennober
IUEM, laboratoire Géosystèmes, UMR6554, place Nicolas Copernic, 29280 Plouzané, France
Gwenaelle.pennober@univ-brest.fr

Résumé

La démarche proposée consiste en la mise au point de méthodes d'analyse spatiale appliquées à l'étude de la géomorphologie littorale en utilisant les opportunités offertes par les SIG et la télédétection. Elle a été élaborée dans le cadre scientifique de la création de la réserve de biosphère de l'archipel des Bijagos pour la gestion de laquelle a été créée une base de données gérée sous Arc/Info. Cette réflexion est basée sur une segmentation multicritère de la zone intertidale décrivant l'espace littoral de l'archipel dans ses formes, ses processus dynamiques et sa cinématique.
L'objectif est de décrire les conditions dynamiques de l'évolution du littoral de l'archipel des Bijagos en montrant les liens d'interdépendance qui existent entre les ensembles morphosédimentaires. Après avoir opéré une segmentation de l'espace littoral fondée sur la mise en relation topologique de la morphologie des petits fonds, des propriétés morphosédimentaires de l'estran et de la nature des contacts terre-estran, chaque ensemble a été renseigné par une série d'attributs décrivant les formes, les processus dynamiques et la cinématique. Une analyse statistique multivariée intégrant la notion de voisinage entre chaque ensemble a ensuite été effectuée afin d'aboutir à la définition d'une typologie dynamique du littoral de l'archipel.

Abstract

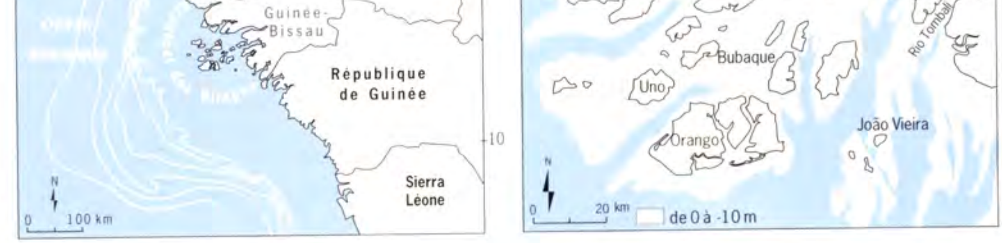
The process proposed here is the application of spatial analysis methods to a coastal geomorphology study by using GIS and remote sensing tools. It was created within the scientific frame of the biosphere reserve of the Bijagos archipelago (Guinea-Bissau) for which a management tool was elaborated through a database created with Arc/Info. This method is based upon a multicriteria segmentation of the intertidal zone describing the archipelago's shape, dynamic process and kinematics.
The goal is to describe the dynamic conditions in which this archipelago's coasts evolve by showing the links between the morphosedimentary groups. After dividing the coastal area according to different criteria, *i.e.* the shallow waters morphology, the morphosedimentary characteristics of the shore, and the type of land-shore transition, each

group is designated by a series of attributes: shape, dynamic processes and kinematics. A multivariate statistical analysis taking into account the neighbouring notion existing between the groups then yields a dynamic typology for the archipelago's coasts.

Introduction

Cette étude décrit les caractéristiques physiques du littoral de l'archipel des Bijagos, partie émergée du delta du même nom (fig. 1). Il s'agit d'un site d'intérêt majeur du point de vue de la géomorphologie : c'est le seul delta actif de la côte ouest africaine et il se situe au point de rencontre des dérives littorales nord et sud (Guilcher, 1954).
Ce travail s'inscrit dans le cadre du programme scientifique associé à la demande de classement de l'archipel des Bijagos en tant que réserve de biosphère (programme MAB de l'Unesco) (Gourmelon & Pennober, 1998). Afin de réaliser le zonage de la réserve, une base d'information géographique (BIG) analysable à 1/50 000 a été constituée sur les milieux terrestre et marin.
La démarche proposée consiste dans la mise au point de méthodes d'analyse spatiale appliquées à l'étude de la géomorphologie littorale en utilisant les opportunités offertes par la géomatique. Cette réflexion est basée sur une segmentation multicritère de la zone intertidale décrivant l'espace littoral de l'archipel dans ses formes, ses processus dynamiques et sa cinématique. Elle doit nécessairement prendre en compte la mise au point de méthodes garantissant le transfert des informations entre les différentes échelles d'analyse et établir les liens topologiques entre les différents modes de représentation spatiale de l'information.

Figure 1
Situation et présentation de l'archipel des Bijagos.



Matériel et méthodes

Une des principales sources d'information de la BIG a été une mosaïque de quatre images Spot datant de 1995, acquises simultanément sur l'ensemble de l'archipel (Pennober, 1999). Les résultats du traitement de ces images ont servi de base pour caractériser les domaines terrestre et marin de l'archipel : l'occupation du sol, les types d'estran, les types d'avant-côte. À partir de ces trois couches d'information, ont été définis les paramètres de la typologie sur la base d'une réflexion menée sur la définition du littoral à retenir.

Définition du littoral et descripteurs pertinents

En géomorphologie littorale, l'option de résumer le littoral au trait de côte est généralement retenue dans des études à petite échelle (Bartlett *et al.*, 1997). Très restrictive, cette représentation rend difficile une approche explicative de la dynamique en raison de la variété des processus à représenter. Le parti pris de cette étude a donc été de représenter l'information sous ses formes les plus pertinentes compte tenu des échelles concernées et de développer les outils méthodologiques permettant de s'affranchir des modes de représentation de l'information. Trois ensembles de descripteurs ont été retenus :

• **les descripteurs morphologiques,** ont pour objectif la représentation du littoral dans ses formes et son évolution. Ils peuvent être couverts par trois variables (Verger *et al.*, 1972) :

- la statique ou étude des formes à un instant donné,
- la cinématique ou l'étude de la dynamique des formes,
- la dynamique ou l'étude des agents qui créent les formes et leurs modifications ;

• **des descripteurs spatiaux** ont été définis, afin de rendre compte de l'interpénétration entre les milieux. Une segmentation « verticale » de la zone littorale a été réalisée. Pour la décrire, quatre unités spatiales ont été retenues :

- *le milieu terrestre* en contact direct avec l'estran. Il se caractérise par un substrat, une occupation du sol et une élévation. Il révèle une sensibilité plus ou moins grande aux attaques marines mais constitue aussi un indicateur de la dynamique des paysages à long terme ;
- *le contact terre-estran,* constitue un indicateur intéressant de la dynamique littorale actuelle ;
- *la zone intertidale,* peut être caractérisée dans ses formes, son substrat, son extension, résultat de la dynamique actuelle, en équilibre ou en recherche d'équilibre entre les formes initiales et les forces en action ;
- *le milieu infratidal* participe au budget sédimentaire de l'estran par le jeu des remaniements marins. Sa morphologie a un impact sur le niveau de protection des littoraux. Elle constitue aussi un indicateur important de la dynamique actuelle de la zone de balancement des marées.

De la description du contexte régional à celle de l'unité paysagère, la difficulté réside dans la sûreté des choix opérés pour représenter les informations pertinentes à un **niveau scalaire** adéquat. Bien qu'il existe un lien fonctionnel étroit entre elles, trois échelles d'étude s'imposent pour comprendre la dynamique littorale actuelle de l'archipel des Bijagos :
- *le niveau régional :* à ce niveau se dégagent le contexte hydroclimatique global et le cadre structural, responsables des grands types de paysage et de morphogenèse ;
- *le niveau du delta :* selon la situation dans l'ensemble sédimentaire, un site est plus ou moins exposé à la houle ou aux agents estuariens (courants de marée et débit fluvial) ;
- *le niveau local* où des facteurs ponctuels peuvent interférer avec les deux précédentes échelles.

• **La prise en compte de la durée** dépend de l'ordre de grandeur des formations étudiées et de leur vitesse d'évolution. À une approche multiscalaire est donc forcément associée une approche multi-temporelle. Deux échelles temporelles d'étude ont été fixées :
- *le court terme* est analysé à partir des données de terrain (1994 et 1995), des photographies aériennes (1981) et des images satellitaires (1973, 1990, 1995). L'exploitation de la base d'information géographique décrit, dans certains cas, les potentialités d'érosion, d'accumulation ou de stabilité du trait de côte en fonction des interactions entre les milieux supratidaux, tidaux et infratidaux ;
- *le long terme* est apprécié à partir de l'étude des formes littorales dans leur succession et leur organisation spatiale.

Exploitation des couches d'information de la BIG

L'organigramme présenté en figure 2 synthétise les couches d'information employées pour l'étude des formations littorales ainsi que la démarche adoptée pour en extraire les informations utiles.

• **La couverture morphobathymétrique,** produite à partir de la combinaison de la bathymétrie numérisée et de l'interprétation de la mosaïque d'images, a servi de base à la définition de paramètres décrivant l'extension de la zone des 10 m, la situation dans l'archipel, la situation à l'échelle locale et la largeur de l'estran. Les paramètres quantitatifs ont été mesurés à l'aide des outils du logiciel Arc/Info ; les paramètres qualitatifs ont été définis par interprétation directe. La présence ou l'absence des bancs prélittoraux ainsi que l'extension de la zone des 10 m (petits fonds) permettent de qualifier le niveau de protection ou d'exposition des différentes parties du littoral. La largeur de l'estran fournit une indication sur l'importance des apports sédimentaires ou des modes de redistribution. Les paramètres ont été codés selon les modalités rencontrées sur l'archipel. Ils ont ensuite été utilisés pour réaliser une segmentation de la zone intertidale décrivant les différents types de milieux littoraux.

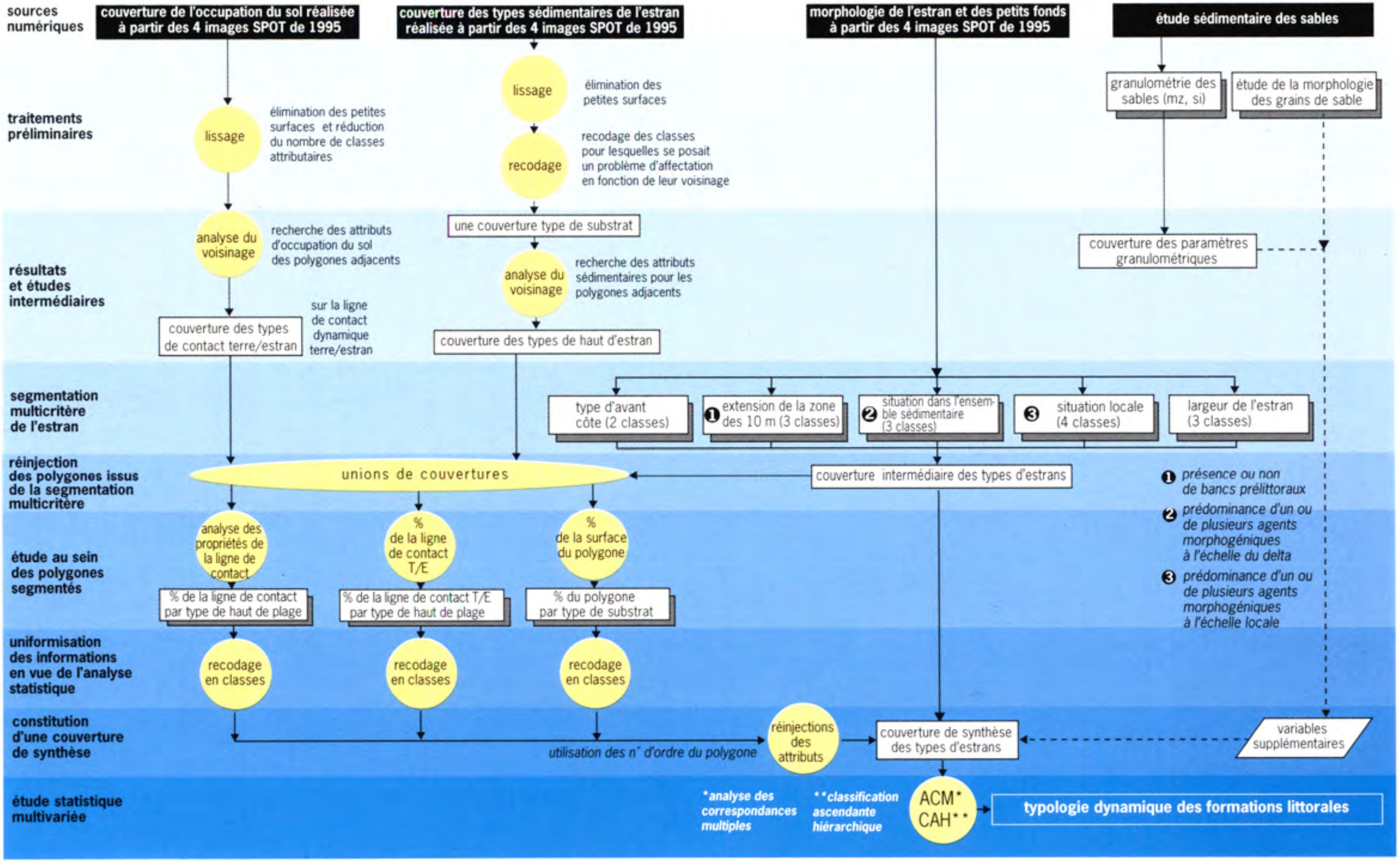


Figure 2 - Organigramme de l'élaboration de la typologie des formations littorales.

• **La couche d'information sur la nature de l'estran,** produite à partir de classifications d'images Spot, décrit la nature de l'estran en trois classes : sableux, sablo-vaseux et rocheux. Elle a donné lieu à la mesure de deux paramètres, calculés en combinant ces trois classes et la segmentation décrite au paragraphe précédent :
- *les faciès de la zone intertidale :* dans chacun des polygones de la segmentation a été calculé le pourcentage de la surface occupée par les trois classes identifiées;
- *le type de haut-estran :* la distinction entre la nature du haut-estran et l'estran a été réalisée afin de prendre en compte des changements éventuels entre le haut et le bas de la zone intertidale (situations assez fréquemment observées sur le terrain). Pour chaque polygone de la segmentation, on considère la limite terre-estran de ce polygone, et on lui associe l'occurrence de chacune des trois classes de nature de l'estran, mesurée à partir des polygones situés au contact de la limite, et donc caractéristiques du haut-estran.
Les pourcentages ainsi calculés sont affectés à l'étiquette du polygone, en tant qu'attributs thématiques.
• **La couche d'information sur l'occupation des sols** a été produite pour la carte de synthèse de l'environnement de l'archipel des Bijagos à 1/50 000. Elle a permis l'analyse des types de contacts estran-terre (étendus à la mangrove). L'analyse de cette couche d'information a donné lieu à la mesure du type de contact terrestre obtenu, d'une manière analogue à la précédente. L'occurrence de chacune des classes d'occupation du sol a été calculée et affectée à l'étiquette du polygone, en tant qu'attributs thématiques. Deux attributs ont été ajoutés au type de contact terre-estran : les falaises et l'extension de la mangrove. C'est dans l'esprit de privilégier la dynamique du milieu que la mangrove et les tannes n'ont pas été intégrés à la zone intertidale. Le contact terre-mangrove est un contact peu dynamique ou seul un exhaussement lent des sols peut modifier l'environnement en laissant petit à petit la place aux tannes. Par contre, le contact mangrove-estran présente une grande dynamique et constitue la partie qui réagit la première aux modifications de l'environnement (nouvelle colonisation, recul).

Analyses spatiales

Les analyses mises en œuvre pour exploiter la BIG sont essentiellement fondées sur l'étude des relations spatiales entre les objets. Compte tenu des choix initiaux, il est nécessaire de pouvoir mettre en relation la ligne de contact entre la terre et l'estran, représentée par un vecteur, et la zone intertidale adjacente, représentée par un polygone. En outre, si l'on considère les relations terre-estran-petits-fonds comme un espace continu en interaction dynamique, il est indispensable d'analyser les liens de dépendance « verticale » entre ces différentes composantes en considérant ces ensembles dynamiques dans leur continuité spatiale « horizontale ».
Pour ce faire, on utilise les propriétés topologiques de la représentation des objets sous forme de vecteurs et de surfaces thématiques afin

d'établir une relation entre leurs attributs thématiques. Un polygone est décrit par une série de vecteurs constituant une limite fermée et par une étiquette d'identification à laquelle sont associés les attributs topologiques internes du polygone (numéro d'ordre, surface, périmètre) ainsi que ses attributs thématiques. La limite du polygone est composée de segments orientés comportant leurs propres attributs topologiques (orientation, numéro d'ordre du polygone de droite, numéro d'ordre du polygone de gauche) ainsi que des attributs thématiques éventuels. On peut déduire de la notion d'entité polygonale que l'analyse du voisinage d'un polygone peut être opérée de la façon suivante :
- interrogation des limites du polygone considéré et identification du numéro d'ordre des polygones adjacents ;
- collecte des attributs thématiques de chaque polygone adjacent à partir de l'identification de son numéro d'ordre.
Les résultats de l'analyse du voisinage ont donné lieu à la création d'un nouvel attribut associé à l'étiquette du polygone central ou affecté en tant qu'attribut thématique au vecteur constituant la limite entre deux polygones adjacents. Ces notions de mise en relation thématique des objets géographiques d'une couche d'information peuvent être transposées à l'emploi de couches multiples.
L'analyse des continuités horizontales, réalisée *a posteriori*, a été exploitée dans l'analyse de la cinématique littorale. Elle a permis de distinguer en particulier les formes d'érosion-accumulation par compensation d'événements plus significatifs de la dynamique à long terme du littoral.

Analyse statistique et typologie

L'analyse statistique multivariée a été réalisée à l'aide du logiciel Addad. Compte tenu de la nature hétérogène des variables, une analyse factorielle en correspondances multiples (ACM) a été employée. L'utilisation d'une ACM se justifie par l'intérêt de mettre en évidence les relations qualitatives qui peuvent exister entre les différentes entités de la zone littorale et de mieux comprendre l'organisation et la dynamique de ces paysages. Elle trouve aussi sa justification par le nombre de variables (20) qualifiant l'estran et le grand nombre de polygones (2 178). Avant de procéder à l'analyse, l'homogénéisation par recodage des données initialement composées de variables quantitatives et qualitatives a été nécessaire. Le choix des classes a été réalisé avec le souci de mettre en valeur des seuils naturels décrivant des unités de paysages, tout en s'efforçant de privilégier des classes d'effectifs sensiblement égaux. Au total, 72 modalités décrivent les vingt variables initiales.
Pour classer les données en unités statistiques homogènes nous avons utilisé une classification ascendante hiérarchique (CAH) - méthode dirigée. Le programme d'analyse de l'ACM, Addad décompose les données sous la forme d'un tableau disjonctif complet. La représentation des données sous forme disjonctive est particulièrement intéressante car elle autorise la prise en compte de relations non linéaires entre les variables pour le calcul des axes factoriels.

Résultats

Les résultats de l'analyse ont été particulièrement complexes à interpréter. Les vingt-cinq premiers axes factoriels ne regroupent que 70 % de l'information, ce qui impose, outre une très longue description analytique des contributions de chaque axe, l'emploi de méthodes de classification pour opérer une synthèse des résultats de l'analyse. La faible inertie des axes s'explique par la relative indépendance qui existe entre les variables. Ce résultat contribue à valider la pertinence des variables qui ont été déduites de l'exploitation de la BIG. Par ailleurs, ces résultats décrivant à la fois les attributs thématiques du milieu littoral et les relations de continuité spatiale entre les différents ensembles traduisent bien la grande diversité paysagère du littoral de l'archipel.

Les trois premiers axes factoriels expliquent 25 % de la variance totale et décrivent les grandes tendances de la répartition des ensembles sédimentaires. Les figures 3 et 4 présentent les résultats du croisement de ces trois axes. L'inertie de chacun des trois premiers axes est la suivante : 10,4 % pour l'axe 1, 9,2 % pour l'axe 2, 5,4 % pour l'axe 3.

L'axe 1 oppose les milieux à prédominance de sédiments sableux à ceux majoritairement composés de sédiments sablo-vaseux.

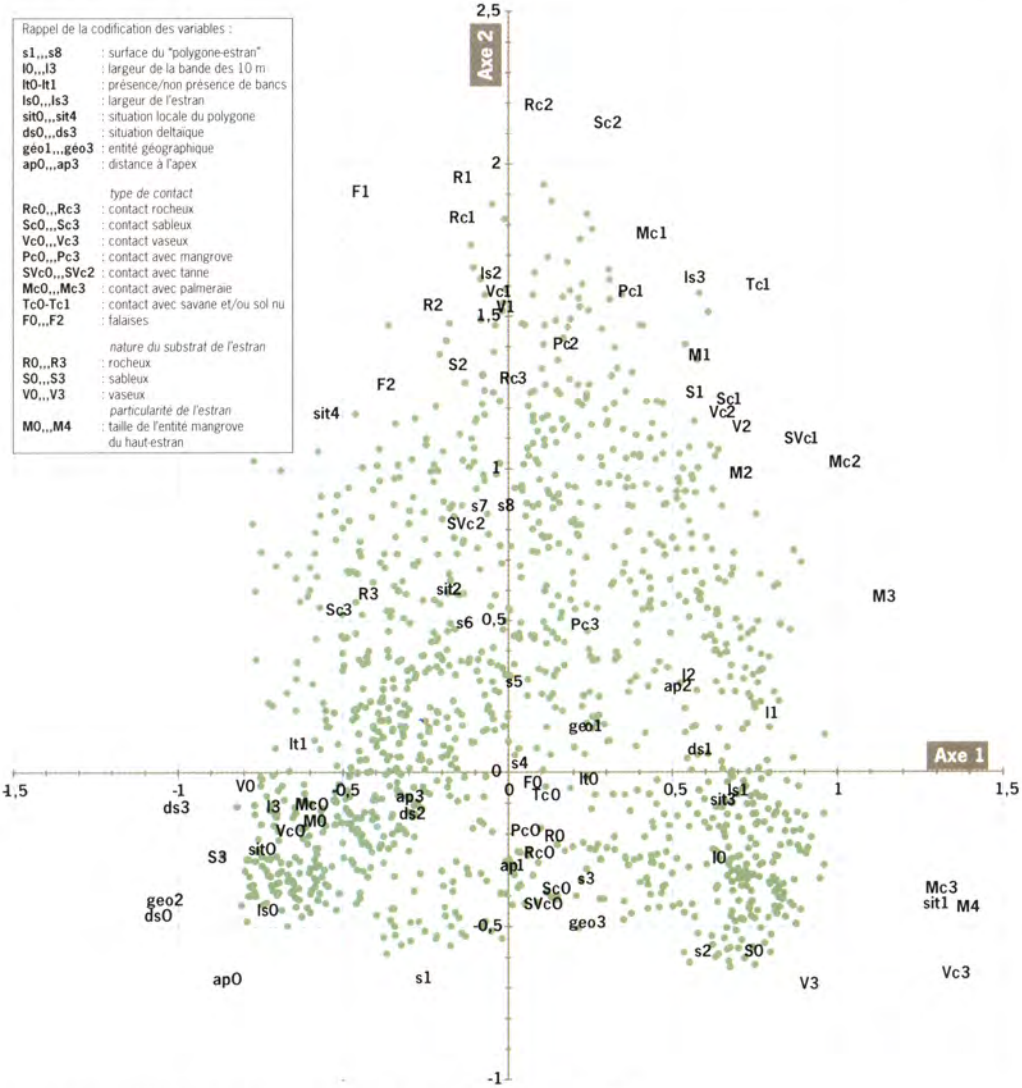
L'axe 2 se caractérise principalement par sa dissymétrie. Il met en évidence les formations rocheuses sans redécouper les deux premiers groupes opposés sur l'axe 1. Le phénomène rocheux s'oppose à toutes les variables impliquant une organisation spatiale et indique ainsi son caractère azonal. Cette information révèle le poids de l'héritage structural. Bien que n'apparaissant que de manière ponctuelle sur le terrain, les buttes rocheuses laissées sur place après la dernière transgression jouent un rôle important dans l'édification de ce delta à divers niveaux en favorisant, en particulier, la sédimentation dans des secteurs relativement exposés aux houles.

L'axe 3 a une bonne symétrie et découpe en sous-ensembles les groupes identifiés sur l'axe 1. Ce découpage est complexe. Il se fonde à la fois sur la distance des milieux à l'embouchure du fleuve et sur une opposition entre les formes liées aux houles, caractérisées par un contact sableux franc, et la partie précontinentale de l'archipel, dans laquelle se trouvent de larges estrans sablo-vaseux et mixtes. Les bolons à sédimentation sablo-vaseuse les plus proches du front marin sont clairement mis en évidence. Le croisement des axes 2 et 3 présente une grande dissymétrie liée à l'axe 2. Aux formations rocheuses et mixtes mises en évidence par l'axe 2, l'axe 3 oppose la partie interne de l'archipel encore exposée aux houles. La taille des estrans semble être dans ce cas un élément explicatif important avec des surfaces de polygones comprises entre 200 et 600 ha et des estrans très larges. Dans ces zones de forte sédimentation, les formations anciennes héritées sont absentes de la zone littorale et laissent place à des formes sédimentaires typiques des ensembles sédimentaires ou deltaïques embryonnaires.

La carte de synthèse présentée en figure 5 résume les grandes tendances du littoral de l'archipel des Bijagos dans ses formes, sa dynamique et sa cinématique. Cette typologie a été élaborée à partir des résultats de la classification ascendante hiérarchique réalisée à l'issue de l'ACM. Elle nous montre une organisation complexe :

- des formes de sédimentation prédominantes avec toutefois une dynamique importante de la partie frontale du delta qui se traduit par des successions de formes d'accumulation et d'érosion. L'examen *a posteriori* des contextes hydrodynamiques de chacun des secteurs de côte identifiés en érosion nous a montré que l'on a essentiellement des systèmes d'érosion-accumulation par compensation ou des formes d'érosion liées à la dynamique des barres d'avant-côte ;

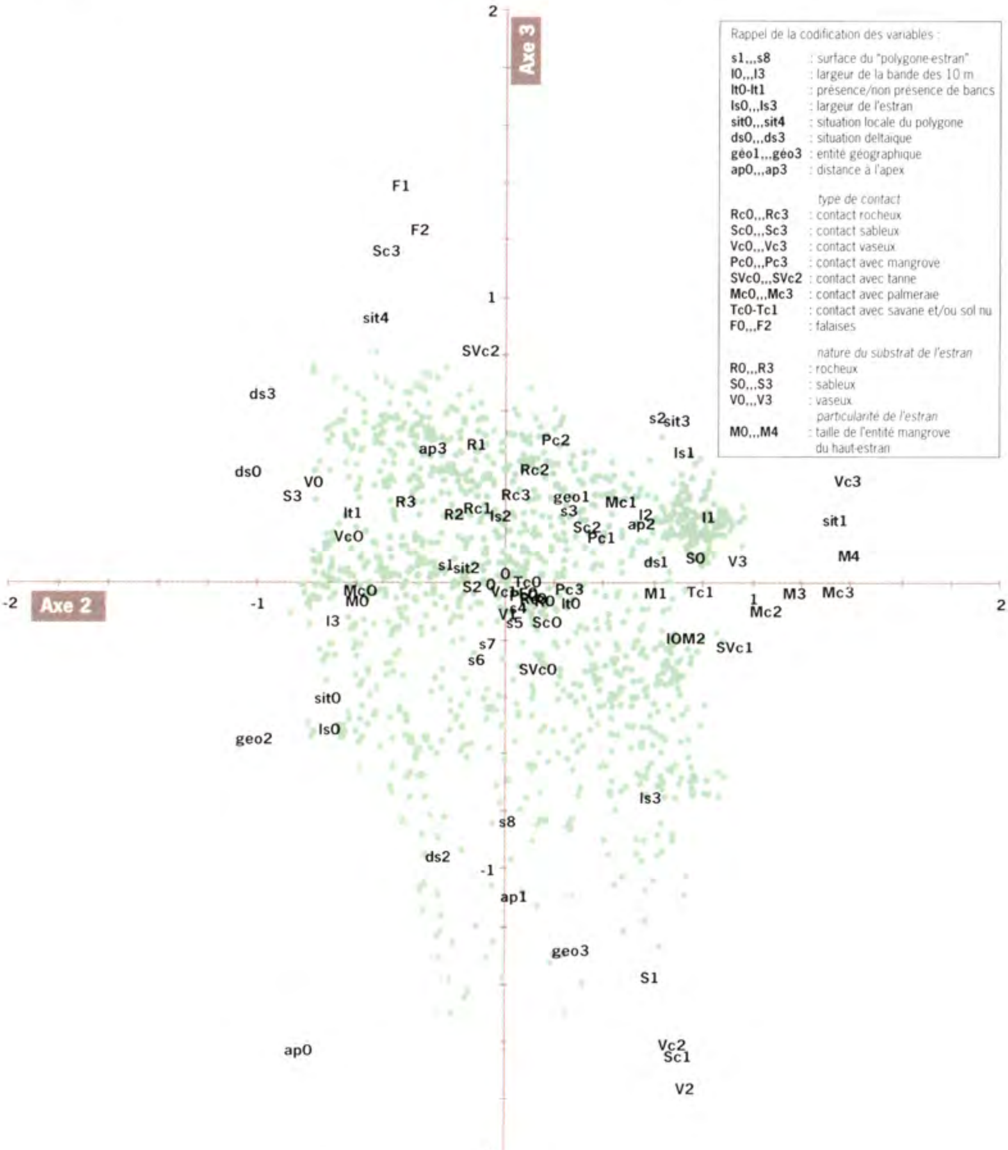
Figure 3
Croisement des axes 1 et 2 de l'ACM.



ACM sur les caractéristiques des polygones de l'estran - variables : 20, polygones : 2177

- une opposition rivage fluvial-rivage marin franche avec toutefois, dans la zone frontale, une imbrication entre les formes estuariennes (bancs alignés par les courants de marée) et marines (cordons construits par les houles). Cette organisation tend à démontrer la prédominance de la marée par rapport aux autres agents de la dynamique.

Figure 4
Croisement des axes 2 et 3 de l'ACM.



ACM sur les caractéristiques des polygones de l'estran - variables : 20, polygones : 2177

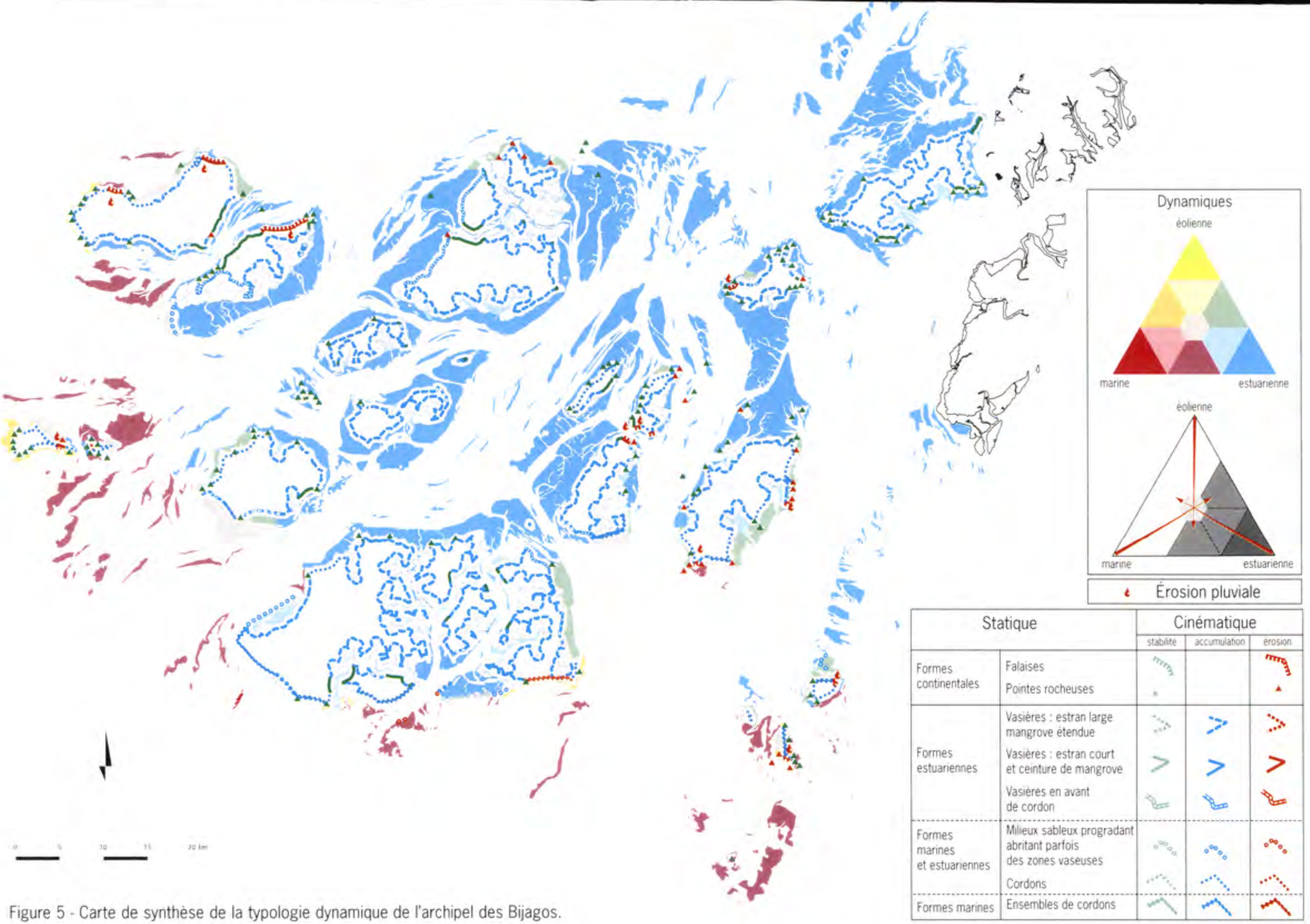


Figure 5 - Carte de synthèse de la typologie dynamique de l'archipel des Bijagos.

Conclusion

L'analyse spatiale dans le cadre de la BIG a abouti à la conception d'une typologie dynamique du littoral de l'archipel des Bijagos. L'ACM a montré les grandes tendances de la distribution des ensembles morphosédimentaires de l'archipel et a confirmé la pertinence de la mesure des liens topologiques entre ces formations.
La réflexion menée sur l'établissement de relations de continuité en zone littorale est juste effleurée dans cette étude. Il serait particulièrement intéressant du point de vue méthodologique d'intégrer cette réflexion dans une démarche de modélisation quantitative des agents de la dynamique et de la sédimentologie par le couplage d'une BIG et de modèles hydrodynamiques.

Références bibliographiques

Bartlett D., Devoy R., McCall S., O'Connell I., 1997. A dynamically segmented linear data model of coast. Mar. Geodesy, 20, 37-51.

Guilcher A., 1954. Dynamique et morphologie des côtes sableuses de l'Afrique Atlantique. Cah. Inf. Géogr., Paris, 57-68.

Gourmelon F., Pennober G., 1998. BijaSIG, un outil d'analyse de l'environnement et d'aide à la planification côtière de l'archipel des Bijagos (Guinée-Bissau). *In:* Actes des VII[e] journées de géographie tropicale îles et littoraux tropicaux, Brest, septembre 1997, 253-260.

Pennober G., 1999. Analyse spatiale de l'environnement côtier de l'archipel des Bijagos (Guinée-Bissau). Thèse de doctorat, université de Bretagne occidentale, Brest, 193 p.

Verger F., Auphan E., Mogniot C., 1972. La carte géomorphologique conçue comme un modèle dynamique. Mém. Doc. publiés sous la direction de Jean Dresh, 43 p.

Chapitre 4

Regulatory aspects

Aspects réglementaires

The integration and management of regulatory data in a GIS: an applied analysis of the French coasts

Brigitte Guillaumont[1], Christophe Durand[2]

(1) Ifremer Brest Del/ao, BP70, 29280 Plouzané, France
bguillau@ifremer.fr
(2) Ifremer Brest Dnis/esi, BP70, 29280 Plouzané, France

Abstract

The management of natural resources and coastal areas involves many regulatory zonings. An analysis carried out, within the context of the French coasts, has revealed many pitfalls in attempting to transform regulatory texts into georeferenced data: disparity of sources, gaps in data, difficulties in arc plotting and conflicting interpretation of the texts. Multiple geometric construction lines, indistinct boundaries and the need to manage the links with textual data add to the complexity in terms of creation, integration and updating of regulatory information within a Geographical Information System. Application examples which transform textual information into structural joined tables are presented. This paper presents the implementation method and the consulting procedures of an accessible intranet database linking textual and geo-referenced information.

Résumé

La gestion des zones côtières met en œuvre de nombreux zonages. Une analyse, conduite dans le contexte des côtes françaises, en vue de la mise en place de bases de données géoréférencées relative aux zonages administratifs et réglementaires a révélé de nombreuses difficultés : disparité des sources, lacunes, difficultés de génération, difficultés d'interprétation des textes juridiques. La multiplicité des éléments géométriques, l'incertitude attachée aux limites et la nécessité de gérer des liens avec les informations textuelles rendent complexes la création, l'intégration et la mise à jour de ces données dans un système d'information géographique. Des exemples d'application illustrant la structuration d'information textuelle sous forme de tables attributaires sont présentés. Une méthode de mise à disposition et de consultation de l'information textuelle et géoréférencée *via* un intranet est également exposée.

Introduction

Everywhere in the world, the coastline is increasingly becoming the subject of interest and attraction. A great number of activities have sprung up along the coastal fringe, as well as in the coastal waters, and conflicts of interest have broken out between business concerns, recreational activities, and the need to draw up environmental protection measures. An increasingly rigorous legal framework has been established in order to limit or constrain by law the various activities and thus ensure their safety and sustainability. The manner in which these regulations have been defined depends very closely on the historical and cultural background of each country and discrepancies appear especially near the coastline. Nevertheless, general outlines can be identified.

Traditionally, the terrestrial part is mainly governed by local and regional authorities. The marine part is under the control of central government agencies which implement a sectoral management. As long as different activities remain low-key, they may be treated separately. However, once activities start proliferating, the division of responsibilities creates an excessive number of rules and regulations, an overlapping of various authorities, and an incompatibility between regulations, as well as their non-application. The gradient organization of the marine environment is not conducive to clear and consensual boundaries. As a result, management decisions often lead to new geographical limits. A sense of balance is thus not attained.

Attempts are currently being made to set up an integrated management of coastal zones. The search for consensus and legal or contractual harmonisation means that the different environmental, socio-economic and administrative approaches must be analysed and the parties involved (politicians, managers, scientists, professionals, associations) must have access to a global overview of the situation.

Because of extensive overlapping between zonings, conventional methods using paper have turned out to be useless. The Geographic Information Systems (GIS) and multi-media tools are likely to contribute greatly to this field as regards the storage and dissemination of geo-referenced data and associated text. They will also help in analysing spatial relationships and in setting up an integrated management of coastal zones.

In this study, carried out within the context of the French coasts, an inventory has been made of the main types of data available in terms of administrative, regulatory or management boundaries or zonings. It takes into account the comparison between land and sea evolutions, the historical changes in regulations, the modalities of geographical transcription and diffusion as well as other emerging needs. The technical specifications linked to the generation, structuring and management of geo-referenced data and associated data within a GIS have been analysed using the ArcInfo and ArcView softwares. Some application examples in progress using GIS are presented. A methodology to disseminate information *via* an intranet Web-GIS coupling is also proposed.

The dynamics of management and regulation methods

Land

The fact that resources on land have a strong spatial character, linked to a sophisticated system of property rights, has contributed greatly to a modified environment where there is a clear separation between the various land uses (and the users). Even though zonings are likely to evolve later, this system acts as a reference.

A "commune" in France constitutes the smallest territorial division. These areas, or grouping of them, are used to form the basis of most management units. They are also taken as references to implement numerous regulations and to collect statistical data.

Legislative or contractual measures aimed at protecting endangered species and areas have recently proliferated at various administrative levels, many of which concern coastal zones (Richard & Dauvin, 1996). Some are located on either side of the land-sea divide. The water catchment areas and the different divisions of the hydrographic network also tend to form significant units, both in terms of the management and implementation of regulations relative to water quality, as well as statistical data collection.

Sea

In the marine environment, free access and the absence of control have been the norm for ages. The main exception concerned a narrow band of seawater, linked mainly to the defence sector. Access rights were controlled by the state. The central government also handled, sector by sector, the dyking, the permanent fisheries and the provisional concessions for marine cultures.

Gradually, it has become necessary to ensure navigational safety, and this has led to stricter and more complex traffic regulations. New international legislations (Montego Bay Convention, 1982) have formalized marine space divisions governing rights in terms of traffic, police, customs, exploration and exploitation both on the surface as well as on the sea bed or in the subsoil.

The development of new activities and the will to improve the management of resources have more recently led to a clearer definition of regulations in terms of limited access, fewer fishing gears and reduction in catches. The marine culture concessions have been diversified geographically and have been extended to deep water areas. Management units, producer organizations have been set up which often involve a spatial dimension. The great increase in the number of ports has led to different statutes, depending on the type of activity, to the demarcation of administrative areas, as well as dredging and dredging waste disposal areas. Activities involving the extraction of aggregates have been tightened up.

The development of tourism, including bathing, leisure boating, fishing, shellfish hunting, scuba diving or nature holidays has also led legislators and managers to define new rules to ensure better control.

The will to protect the environment means that greater attention is paid to elements which belong directly to the sea: sea mammals, fragile habitats. The cultural heritage of the sea also tends to be the subject of conservation measures. Protecting the quality of the environment and safeguarding the health status of the consumers often involve a geographical element.
Since the sea is not usually dedicated to one user, many different uses may succeed one another or may occur simultaneously. The activity areas may shift. The rules and regulations overlap, or change are adapted continuously.

Recent development

In the last few years, a whole array of planning measures, which incorporate (or not) a statutory aspect, have been gradually set up after consultation with the various parties in order to attempt to settle conflicts and ensure sustainable management. Although this undertaking has only enjoyed moderate success up to now, the local authorities have put forward more explicit claims in their attempt to play a more active role in finding a sense of balance between the various activities and to define the boundaries which fall within their scope as regards the sea. However their policing responsibility only covers a restricted zone.

Transcription of georeferenced data

State of the art

"Communal" boundaries are the subject of a systematic transcription on all terrestrial maps. The information represented on the topographic maps have been digitized to constitute the numeric georeferenced databases of the National Geographic Institute (IGN). These data are of general use and can be included as references to build other bases. The protected environmental areas are digitized according to the IGN reference, even though these areas extend as far as the sea. A national network of fresh water data and a specific base have been created according to the IGN reference. In addition, water catchment boundaries and regulatory zonings have been included. High scale data concerning property register data are currently being digitized. All these data are standardised and will be available on a national level, the agencies in charge of their release have been named and the access procedures have been decided.
Concerning the sea, the main available information can be found on the marine charts. In this field, international coordination and a high level of standardisation exist. These charts are drawn and managed by the Hydrographic Division of the French Navy (Shom). All information concerning navigational safety, on the surface or on the sea-bed, are shown. Elements included on marine charts have been used to formalize international law and some charted boundary lines are used in preference to the textual version. All the international boundaries have not

been formalized yet. Some regulatory boundaries concerning fishing activities can also be shown. But because of the limitations imposed by cartographic representation, and the choice of legibility to preserve maritime safety, it is advisable to retain only the jurisdictional information relevant to the navigator. The Shom has started digitizing all the data at its disposal but their formats and current forms restrict operational use. In many cases, only the boundaries are available, rather than the zones, although the latter are essential in analysis work. The electronic version of marine charts (ECDIS) is starting to be set up. A study concerning marine reference product definition has been undertaken (Allain *et al.*, 1999a).

As a result of the limitations mentioned above, and of the different role of these charts in national law, sea charts do not include the main French administration data at sea. For the time being, there is no systematic production of these data in georeferenced form.

The description of these boundaries in textual form is still widely dispersed, not updated sufficiently and some boundaries remain ambiguous. The high and low watermarks are not available in digital form or are inadequate.

Sea farming leases cartography, which was conducted in a sectoral manner by using relative positionings, is in the process of being digitized. Data about parcels are destined for restricted use. At present there is no plan to disseminate marine culture zoning which is nevertheless of vital importance in many applications. The digitizing of boundaries relative to the sanitary classification of production zones is programmed.

Leisure activities imply very precise boundaries which are continually changing. These limits are often defined in terms of distance and can be implemented in the field (buoys…). They are not necessarily displayed on georeferenced documents. The administrative and regulatory data also suffer from the general problems linked to data collected in the marine environment which are often fragmented, incomplete, incompatible and difficult to access (Info-Coast'99, summary report).

In sectoral management, the use of maps established on different scales and projections, as well as imperfections in terms of positioning, were accepted before. But today, as data integration in the form of functional and coherent geographical entities can be incorporated within a GIS, which cancels the limitations of cartographic representation and offers very broad analytical possibilities, a much more rigorous approach is necessary.

A logical analysis of the modalities of construction of georeferenced entities

In order to evaluate the pitfalls and coherence problems as regards jurisdictional boundaries and zones, it was necessary to examine more closely the modalities of construction of georeferenced units by returning to the legal texts which define them. The inventory took into consideration the boundaries, or the zones, designed for the application of jurisdictional or regulatory measures (navigation, resource exploitation, environmental protection), the perimeters under the responsibility of administrative authorities or technical services as well as management units and technical zonings. In face of the sheer extent of the task, this study did not prove to be exhaustive, but an attempt was made to look for the main texts and to propose an in-depth study of demarcated territories so that the principles of construction were revealed.

The first difficulty is to have complete and up to date information. The interpretation of juridical texts is not always obvious and jurisprudence also plays a role. Various studies relative to the law of the sea and of the coast were analysed as well as regional legal monographs which contained clear and updated interpretations regarding fishing regulations (Slomp, 1995; Cidam, 1999). Different legal text servers were also consulted and a jurist was asked to achieve a complementary study (Tierny, 1998).

On analysing the construction methods, it was possible to identify the "elementary bricks" (lines or polygons) and to distinguish between the reference elements, shared by various boundaries and zones, and the data belonging to one given regulation. These elementary bricks were then confronted with the georeferenced data already available in map or digital form. The detailed inventory of the types of boundaries and zones, definitions, construction modalities, data sources, gaps, existing or foreseeable requirements, problems of coherence, and product proposals are included in the Shom-Ifremer working group report (Allain *et al.*, 1999 b).

The next step is to organize, with these elementary bricks, the logical and hierarchical generation of constructions in such a way as to keep the whole set-up as coherent as possible. Some zones can be considered totally autonomous. They may also result from the combination of other zones or buffering operations. But in most cases, zones are determined by a reference to a landward, seaward and lateral boundaries. In order to facilitate operational use, and to set up data conceptual models structuring the hierarchical construction, functional entities corresponding to the most common uses, and derived from an extensive consultation practice, have to be highlighted.

The updating process seems essential in this thematic domain as the data are strongly interdependent and there may well be numerous reasons for updating: publication of new texts, interpretation errors and jurisprudence, non-stability of reference objects, temporal variability of construction elements...

Generation of geometric elements

The sources of available digital data are widely dispersed and sometimes there are formats which are specific to an organization which renders the problem of information exchange even more complex. The marine charts and the French topographical land maps are not drawn up using the same projections and do not use the same geodesic systems or the same ellipsoids. Although these problems may be overcome theoretically, the transformation tools are not available in standard software,

and they do not provide sufficient accuracy. Users hesitate to use them and errors may increase with the succession of operations.
In the sea environment, most "elementary bricks", especially reference elements, do not exist in a stable and standard form, and they are currently under study. The Shom coastline is only available in a form which meets navigational safety standards. There is no compliance with the IGN high watermark, as regards the tidal term and in estuaries the digitized bank lines do not reach the salt water boundary. Similar problems exist in terms of the hydrographic zero. Moreover, problems linked to operating rights (mainly with IGN) are proving to be considerable stumbling blocks as regards the dissemination of regulatory data for the general public.
There is a great diversity of demarcation methods in use, even for the same zone (all the following examples are extracts from various by-laws relative to the sanitary classification of shellfish production zones). The support base could be geographical co-ordinates, arbitrary lines such as meridians or parallel lines, constant azimuth lines, alignments as well as preexisting jurisdictional boundaries or zones. These zones can also choose as references natural or artificial geodesic elements, some of which are displayed on marine charts or land maps. Whereas others are only known locally or are imprecise. It could be a question of distances in relation to these objects. Some of these construction modes cause transcription or precision problems when detailed research is required (IHO, 1990):
- the transfer of geographical co-ordinates demands a certain knowledge of the geodesic system and the reference ellipsoid. However this information is not usually displayed in national documents;
- the distances shown on the charts must take account of scale variations which exist in many projections. Large distances must be calculated in geodesic terms;
- in the case of demarcations drawn up according to the principle of an equidistance line between two coasts (opposite or adjacent) automatic calculation processes are not necessarily the most suitable;
- lines perpendicular to the general direction of the coast can be constructed if the direction has actually been determined. Protocols have been introduced using the azimuth of lines linking regularly spaced out points on a stretch of coast which is yet to be defined. This mean direction is a loxodrome which can easily be deduced in a Mercator projection, but errors will probably appear using other types of projections or geodesic calculations. Definitions such as "the prolongation of land frontiers" are even more inaccurate and difficult to implement;
- the notion of "thalweg", a maximum depth line along a channel deduced from geographical data, is used when it is advisable not to place a navigational channel under one sole control of one state. In unstable areas, stationary lines can be used by defining fixed extremities on land and on the sea. In order to determine the foot of the continental shelf, detailed protocols have been drawn up to define the point of maximum change of gradient;

- different methods have been proposed to calculate coastal lengths (IHO, 1990) which tend to become a reference unit for instance in the calculation of equalization funds. Standardisation in terms of reference and procedure choice should be defined more accurately;
- some regulations are defined according to physiographic entities which are variable in time, such as the water boundary at time "t". All this requires the implementation of hydrodynamic models or boundary representation or extreme zones of extension.

Structuring geometric data

The vector form appears to be the most appropriate as regards the original management of the data concerned. The geometric data structuring must be the result of a comparison between firstly ease of access to the required functional entities corresponding to the most common uses, secondly the technical skills of the users in meeting their own requirements and thirdly, the generation and coherent management difficulties in the updating process.

At the present time, the update and follow up of data propagation from the operational point of view are proving to be quite tricky (Badard, 1998). Moreover, until now, the arcs available in most marine databases are not codified, numerous arcs are common to several zones which in turn overlap, the intersections being rarely broken down into significant units and zone construction protocols are rarely explicit. For example, the substitution of a new high watermark, without changing the other boundaries of a zone, may have serious repercussions if the structuring of the data has not been pre-programmed.

Ideally, it would be interesting to keep the physical links: nodes/arc/arc_groupings/polygons/polygon_ groupings. In this case, a functional "boundary" may be formed from one or several arcs and a regulatory "zone" may constitute one or several polygons (originating from the assembly of several functional boundaries).

The possibility of keeping construction links between the different entities is not a common feature of GIS tools available for administration use. Only limited management facilities are available in most cases, and thus point, linear or surface objects are managed in a totally disjointed manner (for instance ArcView software). In this case only manual corrective operations are possible in terms of the polygons; unless, of course, these polygons are reconstructed logically from the boundaries, but this involves losing the attributes attached to them.

The Arc/Info software offers a solution which is close to the desired model, in the form of "routes", thus enabling arc associations to be defined (*i.e.* legal boundaries) as well as "regions" formed by a set of arcs demarcating the zone in question or by a set of polygons. However, "a region" cannot be defined by "routes", there is no direct construction link between the two objects.

In order to avoid duplication of common arcs, all the arcs can be assembled together in one single layer (fig. 1, 2).

Figure 1
Display of a set
of regulatory arcs
(pertuis Charentais area).

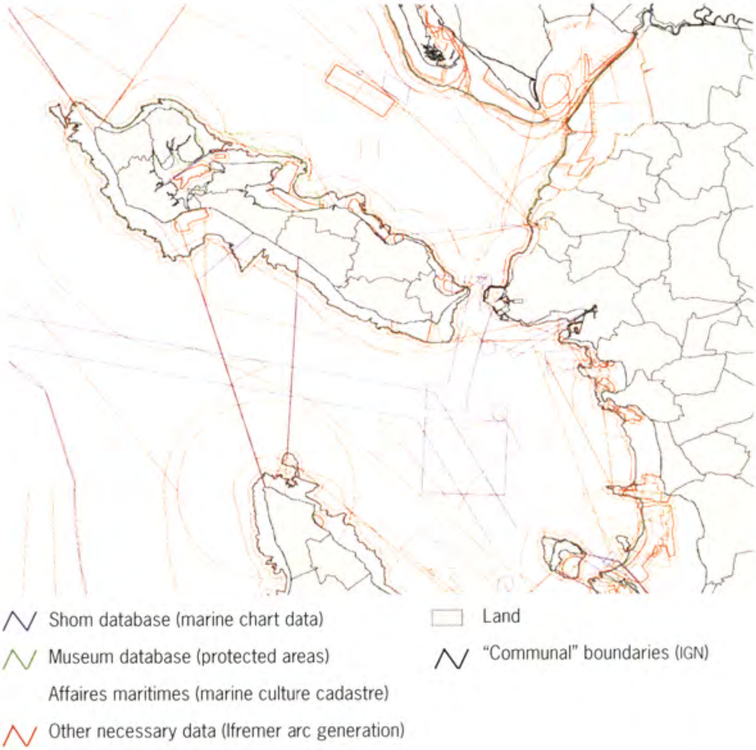
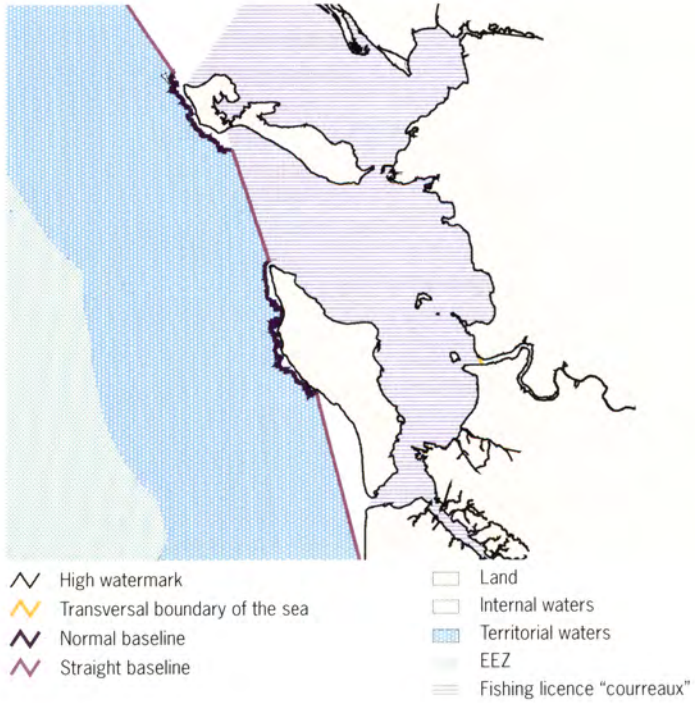


Figure 2
Example of overlapping
between two zones having
common arcs (high
watermark and partly
the base line): internal
waters and fishing
licence zone.



This means that all the elements are managed at time "t" and the original data source can also be retained. Unfortunately, a certain number of problems appear during updating. It is not possible to lock definitively some data or to ensure a certain hierarchy with respect to the integrity of the defined elements. The introduction of new arcs, close to existing ones, is likely to cause deformations and especially discontinuities regarding those boundaries which have already been constructed. The use of very short distances, during the topological construction phase, slows down operations considerably when the base increases in size and, above all, it does not provide absolute guarantee as regards the eventual substitution of one arc by another in the case of arcs in proximity. Furthermore, these discontinuities are difficult to detect as they are very small and there is a great number of non-significant intersections. The problem is raised systematically when areas which do not share the same legal signification, or the same evolution, are superimposed on the same place.

A compromise has been achieved by keeping one single layer of arcs and "routes", from which the required entities are extracted in order to build coherent sets of "regions". These are managed independently and, after the topological construction phase, modification control procedures are implemented. It is essential to optimise the number of layers in order to reduce arc duplication (high watermark, for example) with all the risks involved in differentiating round contours and in updating.

Most of the data concerning a zone are defined by a restricted number of summits, so that, when the duplication of complex arcs is reduced, the volume of information obtained is relatively limited. This allows vast geographical settings to be managed. Thus, it seems easier to envisage coherent management by separating groups of entity types on vast geographical settings rather than attempting to manage all the information on a more limited territory.

Most regulatory arcs do not depend on the scales concerned. In general, it is the direct or indirect participation of physiographical boundaries in the composition of boundaries or zones which determines the scales. However there is a problem of continuity concerning the representation of estuaries. Logically speaking, the coastline should extend landwards in the estuaries until the distance between the two banks corresponds to the level of precision given by the data. This principle has been adopted by Shom but the IGN line is cut arbitrarily seawards. If an exhaustive representation of legal boundaries or sections within estuaries is required, the current system can only be used on the foreshore with respect to the boundary retained. Landward, another representation method, managed independently, must be implemented by taking into account the arcs of the hydrographical network. The legal boundary is thus represented by a node and the sector by arcs. The switch from one mode to the other depends on the scale. The display of exhaustive inventories of variable sized entities may also require management in terms of node and/or polygon objects.

Management of associated information within a GIS, application examples

In a GIS, characteristics or properties can be associated in the form of attributes to primary elements (nodes, arcs, polygons), simple geographical objects (nodes, lines or surface), or complex objects, as well as to relationships between these objects. They are managed in tables and linked with the identifier of the entity concerned.

Links with textual information

The original information (which includes the authority concerned, restrictions of use, the protection level, conditions of application...) is mainly in textual form. The legal texts are still of prime importance because they are written in a refined and precise manner. They express all the required subtleties and they sometimes deliberately leave scope for interpretation. Therefore it is not only advisable, but also imperative that multimedia links should be preserved between the geographical data and the texts concerned.

An extension of ArcView, "DocLink" was developed in order to combine a large range of documents (images, text files, Web sites) with a "theme" or individual objects of themes. Doclink is also used to manage the link with the metadata of the "theme" concerned.

The metadata which include data sources and acquisition methods, the chain of operations applied and the addresses of the organizations in charge are managed by the Reports software according to European standards.

Thematic formalization in view of carrying out analytical and synthetic studies

Apart from information leading to the tracebility of arcs according to their origin, the sole identifier of the entity and the reference in the legal text (as well as the writer, the date of issue and the expiring date), it is also advisable in the case of regulatory data to program a qualification phase, relative to the degree of reliability so that incertitudes can be identified and viewed easily (Palmer, 1998).

In spite of the restrictions mentioned above, in order to take full advantage of the potentiality within a GIS in terms of spatial analysis and synthetic representation, it is necessary to formalise a "conversion method" as regards the original text by setting out parameters and manageable significant variables in attributive tables.

In some cases, the significant information is relatively obvious and does not raise any structuring problems. However, if there is a request to know the restrictions exerted on an activity, it is necessary to set up a link between a type of precise zoning, a given activity and a type of restriction. The restriction typology may prove to be simple (authorized/banned zones) or may require a more subtle formalization (without priority, intermittent prohibition, hierarchical typology of restriction between activities...). The degree of refinement depends on the targeted application. As some measures are applicable according to defined periods and some temporary measures can suspend for a certain time a pre-existing statute, the process may turn out to be complex.

Due to the number of zonings concerning each activity, existing overlaps, and subtleties to be included in the display, graphic semiology must be adapted. An application example concerning space allocation to various fishing boats in the "pertuis Charentais" zone has been developed by Guillaumont & Durand (1997), an example of complementary crossing involving constraints relative to the natural environment has been presented by Allain *et al.* (1999a).

This type of analysis can also contribute to a spatial refinement of fish production data, which are currently only available in large squared statistics, and to the selection of favourable sites in view of a new activity (Durand *et al.*, 1994).

In terms of environmental protection, it may be possible to manage information relative firstly to spatial or species characteristics, secondly to property status and parties involved, thirdly to the objectives and the stage of intervention. By interlinking information it is possible to check the appropriate level of protection with respect to the type of environment and to the risks involved. It is easy to detect the accumulation of different forms of protection in the same space which is accepted from the jurisdictional standpoint as a sign of ecological value.

Example of broadcasting information via a GIS - Web coupling

In order to help Ifremer coastal laboratories, an intranet Web site (multi-user option) has been developed using a Windows NT server. Its incrementation is in progress. Thanks to this system, it is possible to manage, search for and display textual jurisdictional information and also link up with the data available on a GIS. Pages concerning filiation and comments help clarify the general context and facilitate the link to georeferenced data. The Frontpage 98 software defines the interface, the hypertext links and the tree diagrams.

Tools which ensure the management, classification and search for documents have been developed internally. Search can be conducted by text type, chronological order, thematic key-words, zoning type, as well as the implementation of search drives.

By surfing the Web, it is also possible to make requests which activate dynamic chart servers, so that a user who is unfamiliar with GIS can access cartographic information interactively: close-up functions, display of associated supplementary information concerning the chart, themes or objects. This application is implemented by a cartograhic server (CartaGen) which is parametrized by a preparation tool (CartaPrep).

The CartaGen cartographic server generates the chart on request and transfers the information to the Web user in the form of a HTML code, with a GIF formatted chart image. It has been developed in the Visual Basic environment and is based on Map Objects ™ and Internet Map Server ™ products from ESRI.

With CartaPrep users can describe in the ArcView GIS ^{TM} environment the maps to serve: view size and scale, themes, legends, labels, links (using DocLink). The CartaPrep "Serve maps" function then generates a file which configures a CartaGen Map Server.
The georeferenced data originate from agreements made between various producers (Shom, Diren, National Museum, Maritime Authorities...) as well as Ifremer logging and formatting.
This system authorises the updating of displayed data at any moment. It can also broadcast documents resulting from a specific analysis or synthesis. An example illustrating the interface and implantation of these consulting procedures is accessible on the Ifremer Internet site *www.ifremer.fr/posnav* where the positions of the Institute's oceanographic fleet can be observed.

Conclusion

The most important principles in the construction of georeferenced regulation entities have been drawn up. The main obstacles or technical difficulties regarding the generation, integration and management of georeferenced regulation entities in a GIS have been specified and appropriate structuring modes analysed. The organization of associated data was also presented in view of facilitating analytical and synthetic approaches relative to space and activity based constraints. There is also a description of tools available for users to access the information more easily. Detailed and illustrated examples of this analysis are available on the Ifremer Internet site *www.Ifremer.fr/anglais/org/delao.htm*.
Pitfalls in current georeferenced data mainly concern boundaries defined in distance and administrative boundaries. Even if these limits are defined theoretically, due to the complexity of the mapping transcription or negotiations needed, they are not implemented. At the present time, although there are many boundaries parallel to the coast, transversal boundaries which divide the coastline are very few.
The technical report drawn up by the Shom-Ifremer working group about reference data should lead to further analysis in collaboration with other partners, and also initiate a more global approach concerning georeferenced information in the shoreline field.
Data production organization must firstly take into account structuring data and the definition of the required functional units. France has decided to adopt a geodesic system and a single ellipsoid (RGF 93). This should help in making the land-sea data more coherent. The building of a European base means that prior harmonisation of marine references is necessary.
Technical improvements will contribute to optimising the differential updating of georeferenced data which is crucial in this thematic field. Only the 2D transcription has been included in this study, but since this information may concern the surface, the sea floor (even the subsoil), the water column or several of these elements, and the temporal dynamic aspect is equally interesting, other types of representation

could be considered in the future using 3D or 4D. Further improvements are also needed in terms of the GIS-Web coupling.

Disseminating information on the Internet is hampered mainly by broadcasting rights. The problem is especially serious as regards the high-watermark, which is involved in the construction of a great number of zonings.

It is equally important that there is better communication in the field of jurisdictional information. The setting up of systematic monographies according to each field of activity is likely to facilitate intersectoral communication. It is necessary to develop networks of thematic jurisdictional monitoring and textual databases. As the transcription of rights is becoming increasingly more accurate in terms of georeferenced data (digital management, positioning), it is important for legal advisors and technicians to co-operate more closely together in order to better define and interpret the law.

The development of GIS and georeferenced databases can play a major role in improving the dissemination and coherency of existing boundaries and zonings and in defining new management zonings resulting from multi-parameter analysis. It is also essential to reflect about the objectives, the parties concerned, and the systems which lead to the setting up of these zonings, in order to find ways and means of simplifying the procedures. This must be done in the light of foreign experience, and furthermore, the sociological and economic repercussions of space specialisation must not be overlooked. It would also be interesting to have units which are common to several fields, and which are stable and small enough to ensure the collection of statistics, as is the case on land.

Bibliographic references

Allain S., Guillaumont B., Le Visage C., Loubersac L., Populus J., 1999(a). Données géographiques de référence en domaine littoral. *In:* CoastGIS'99, Brest, sept. 1999, Éd. Ifremer, Actes Colloq., 25, 67-79.

Allain S., Guillaumont B., Le Visage C., Loubersac L., Populus J., 1999(b). Données géographiques de référence en domaine littoral. Rapport du groupe de travail Shom-Ifremer, 142 p. (sous presse).

Badard T., 1998. Premières pistes pour une mise à jour générique des bases de données géographiques. Bull. Inf. IGN, 69, 1-9, février 1998.

Cidam, 1999. Police des pêches maritimes en Bretagne : guide pratique, éléments généraux de la police des pêches. Cidam, Bordeaux, 227 p.

Durand H., Guillaumont B., Loarer R., Loubersac L., Heral M., Prou J., 1994. An example of GIS potentiality for coastal zone management: preselection of submerged oyster culture areas near Marennes-Oléron. *In:* Proc. EARSeL workshop on remote sensing and GIS for coastal zone management, Delft Pays-Bas, octobre, 9 p.

Guillaumont B., Durand C., 1997. Développement d'une maquette préliminaire de Sirs appliqué à la réglementation des activités maritimes de la mer des Pertuis, France. *In:* C. R. Journ. thématiques sur le spatial et groupe de travail SIG, Assoc. Fr. Halieumétrie, Nantes, février 1997, 11 p.

IHO, 1990. A manual on technical aspects of the United Nations convention on the law of the sea-1982. IHO (eds) spécial publication 51, 237 p, 2nd ed., December 1990, Monaco.

Palmer H.,1998. GIS applications to maritime boundary definitions. International diplomacy on and under the sea. ESRI user conference'98.

Richard D., Dauvin J.C., 1996. Conservation strategies for French coastal areas. *In:* Aquatic conservation: marine and freshwater ecosystems, John Wiley & sons (eds), 6, 205-214.

Slomp W., 1995. Réglementation des activités maritimes en Charente-Maritime : pêche professionnelle et amateur, salubrité, mareyage, épaves et chasse maritime. Affaires maritimes de La Rochelle, service économique, 91 p.

Tierny E., 1998. Étude sur l'insertion d'une base de données juridique dans un système d'information géographique. Rapport de contrat Ifremer-CDMO, 1998, 15 p. + 101 p. annexes.

We are grateful to:
F. Bernard, T. Carval, C. Combrié, M. Delobel, E. Faure, N. Fenard, A. François, G. Le Corre, E. Tierny for their contribution to this work.

Georeferencing the legal framework for a Web-based Regional Ocean Management Geographic Information System

Cindy Fowler[1], Éric Treml[2], Hamilton Smillie[2]

(1) NOAA, Coastal Services Center, 2234 South Hubson Ave., Charleston, South-Carolina, USA
cfowler@csc.noaa.gov

(2) Technology Planning and Management Corporation, Coastal Services Center, Charleston, South-Carolina, USA

Abstract

The Truman Proclamation (1945) and the Law of the Sea Conventions (1958, 1960, 1973, and 1982) initiated a deluge of claims on the world's high seas. As coastal nations subdivided the ocean and developed governance frameworks, inadequate consideration was sometimes given to the spatial integrity of maritime boundaries, delineating sovereignty, regulatory boundaries, and jurisdictional areas. As a result, some present-day boundaries are ambulatory and many co-ordinates are of mixed datums and accuracies that could result in misinterpretation. To help establish spatially legitimate digital boundaries that can be used to improve ocean management strategies, the Coastal Services Center (CSC) of the National Oceanic and Atmospheric Administration (NOAA), working with four states in the southeastern US, has been examining existing boundaries and their spatial accuracy. This is part of an ongoing project to develop a Web-based regional ocean governance and management geographic information system. Major features of the site include an interactive mapping application, marine and coastal spatial data and download tools, associated metadata, and legal summary pages, all designed to support regional ocean management. Integral to the functionality of the project is the inclusion of georeferenced regulatory data layers (georegulations). Georegulations are spatial "footprints" of the geographic area where US federal policies apply. These georegulations allow users to view the spatial extent of federal regulations and maritime boundaries and the overlap they share with natural resources data. Laws are quite often vague with respect to referencing precise geographic boundaries of applicability. Hence, the process of georeferencing the legal framework can highlight deficiencies in spatial extent, boundary delineation, and legal documentation. As a result, much effort has been made to identify and document these errors and suggest possible solutions.

Résumé

La proclamation de Truman (1945) et les conventions des lois de la mer (1958, 1960, 1973 et 1982) ont initié un déluge de revendications sur les mers du monde. Tandis que les nations côtières subdivisaient les océans et développaient des structures de contrôle, une considération insuffisante a parfois été donnée à l'intégrité spatiale des limites maritimes délimitant la souveraineté, les limites de contrôle et les régions juridiques. En conséquence, certaines limites actuelles sont mobiles et de nombreuses coordonnées ont des points de repère mixtes et une exactitude qui pourraient aboutir à une interprétation incorrecte. Pour aider à l'établissement de limites digitales légitimes spatialement et pouvant être utilisées pour améliorer les stratégies de gestion de la mer, le Coastal Services Center (CSC) de la National Oceanic and Atmospheric Administration, qui travaille avec quatre états dans le sud-est des États-Unis, est en train d'examiner les limites existantes et leur exactitude spatiale. Ceci fait partie d'un projet continu de développement d'un système d'information géographique pour le contrôle et la gestion régionale de la mer, basé sur l'Internet. Les caractéristiques principales du site incluent un programme cartographique interactif, des données spatiales maritimes et côtières et des outils de téléchargement, des métadonnées associées, et des pages de résumés juridiques, tous conçus pour soutenir la gestion régionale de la mer. L'inclusion des pages de données réglementaires géoréférencées (géorèglements) est une fonctionnalité du projet. Les géorèglements sont les points de repères spatiaux de la région géographique où les politiques du gouvernement fédéral des États-Unis s'appliquent. Ces géorèglements permettent aux utilisateurs de voir l'étendue des règlements fédéraux et des limites maritimes, et leur chevauchement avec les données de ressources naturelles. Les lois sont souvent vagues en ce qui concerne les limites géographiques précises. Le processus de géoréférencement de la structure légale peut souligner les défauts spatiaux, la délimitation des frontières et la documentation légale. En conséquence, un grand effort a été fait pour identifier et documenter ces erreurs et suggérer des solutions.

Introduction

Currently in the US, the existing institutional framework for managing offshore resources is a fragmented and complex system that is often poorly understood. There is increasing pressure to use offshore natural resources and often these uses are in direct conflict (*e.g.*, fishing *vs.* oil extraction). A variety of laws, regulations, programs, and special jurisdictions have evolved over time to protect, develop, and manage ocean resources. Ocean policies and programs, however, have historically been developed and implemented as single-purpose regimes, with little thought to how they would interact with other resource management considerations (NRC, 1997). In the US there is an overlapping horizontal as well as vertical management structure that increases the complexity. This has resulted in a nation that is ill equipped to address the inevitable conflicts and problems arising offshore.

Many of the ocean issues have a spatial component that can be analysed using advanced mapping technologies, such as a Geographic Information System (GIS). The ability to visualise regulations, laws, or management structures can assist policy makers in understanding ocean use conflicts, help to point out inconsistencies in national or state policy, and educate the public on ocean issues. Many of the natural resource data are available in map form, but US laws and regulations have not generally contained the necessary components to adequately map their spatial extents.

To help establish functional digital boundaries that can be used to improve ocean management strategies, the NOAA Coastal Services Center, working with four states in the southeastern US, has been examining existing boundaries and their spatial accuracy. This is part of an ongoing project to develop a Web-based regional Ocean Planning Information System (OPIS).

Figure 1 shows the OPIS study area. Integral to the functionality of the OPIS project is the inclusion of georeferenced regulatory information in conjunction with the natural resources data. This involved researching the federal and state policy framework in the region and creating spatial

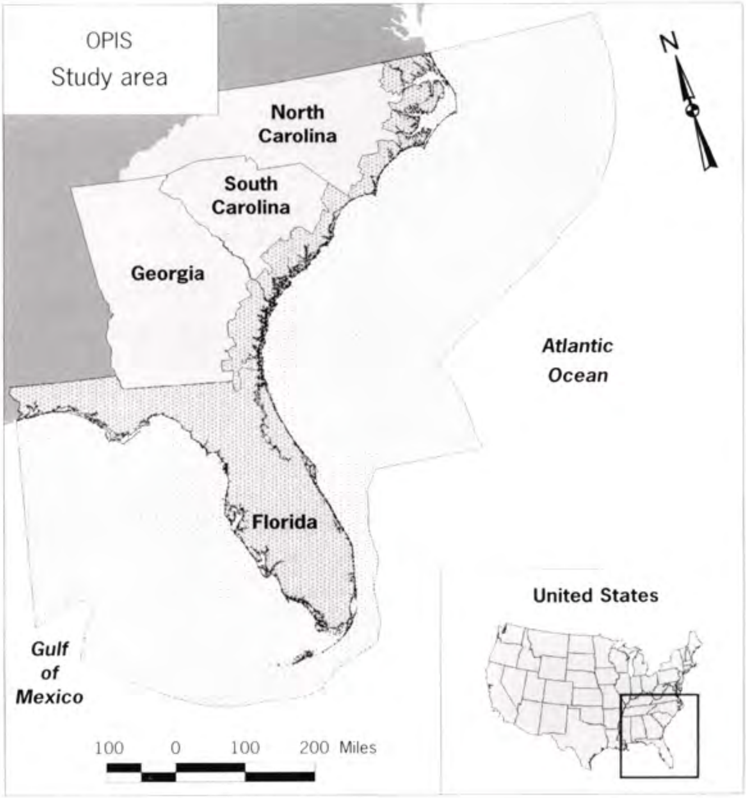


Figure 1
The Ocean Planning Information System (OPIS) study area extends from the States coastal zone to the outer limit of the United State's Exclusive Economic Zone.

georegulations, the geographic representation of the region(s) of applicability on the earth. Because policy makers, not geographers, generally write regulations, the challenge is to adequately capture the geography intended by each individual law. These georegulations, once created, allow users to visualise the spatial extent of regulations and maritime boundaries, as well as make visual comparisons between these laws and natural resources data. In addition, OPIS allows the user to query an area on a map and reveal all of the regulations and managing agencies applicable at that point.

The Marine Cadastre and Policy Framework

To link the policy with the geography for the OPIS project required a technical and geographic analysis of the marine boundaries (cadastres) and the regulatory structure that applies to the area. The marine cadastre, similar to its land equivalent, describes the property interests or the geographic extent of the past, current, and future rights and interests in the ocean. This includes the delineation of private, state, national, and international rights. Unlike the land-based counterparts, however, the marine geography is further complicated by the inability to include any physical boundary markers, such as benchmarks, stakes, fences, or hedgerows, which are used on land. US law for this region has developed from a combination of civil law (originating in ancient Rome) and common law which evolved in England (Graber, 1980). In addition, though currently unratified in the US, many of the principles outlined in the *1982 United Nations Convention on the Law of the Sea* (United Nations, LOS, 1997) have been used to determine the marine cadastre in the US The boundaries can generally be divided into two categories: international and national. The international boundaries include such items as the Contiguous Zone, 12 miles Territorial Sea, and the Exclusive Economic Zone. The national boundaries include the Seaward State Boundary, the Revenue Sharing Boundary (Section 8[g] of the Outer Continental Shelf Lands Act), state lateral boundaries, marine protected areas, other offshore-restricted zones, and the outer continental shelf lease blocks[1].

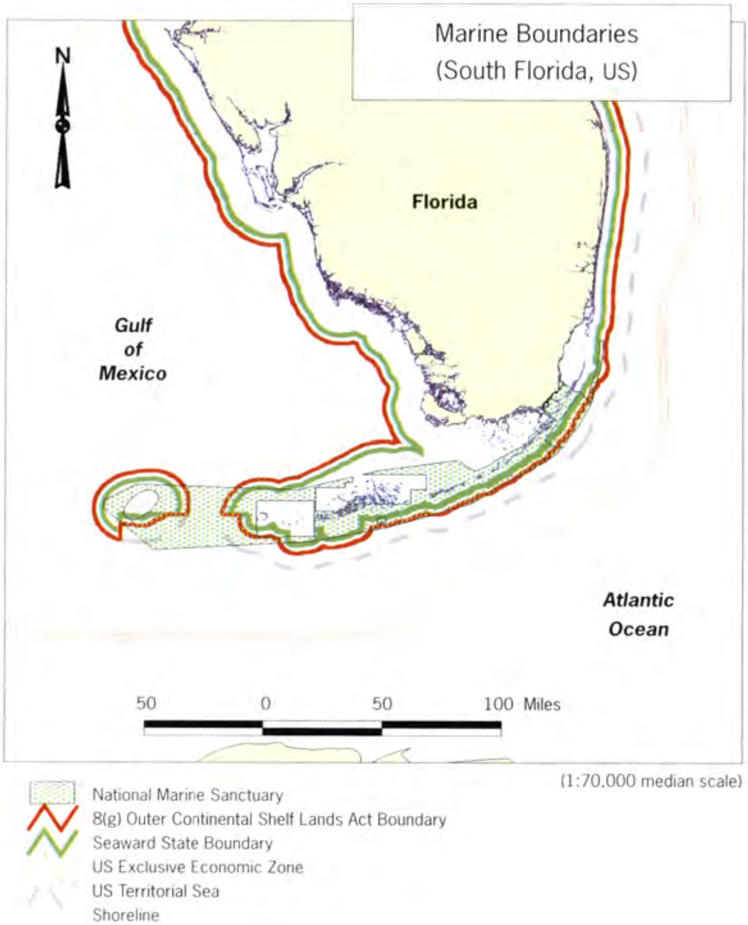
Rights and responsibilities associated with the marine cadastre are often complex with overlapping authorities and jurisdictions at both the State and Federal levels. Generally under US law, individual states (in this case Florida, Georgia, North Carolina, and South Carolina) have the authority to manage, administer, lease, develop, and use the natural resources of the ocean from mean high water out to the 3 nautical mile seaward state boundary (43 USC §§ 1301 et seq.)[2]. However,

1. The Minerals Management Service is responsible for the development and management of the mineral resources on the outer continental shelf within US jurisdiction. The outer continental shelf lease blocks are used to accurately and legally define areas on the continental shelf in support of this Federal oil, gas, and mineral leasing program.

2 The exception to this is the west coast of Florida (Gulf of Mexico side) which has jurisdiction out to 3 leagues or 9 nautical miles.

the federal government retains considerable control over commerce, navigation, defence, fisheries, and international matters. Under section 8(g) of the Outer Continental Shelf Lands Act, states share federal revenues within 3 nautical miles beyond their state seaward boundary (43 USC §§ 1303 et seq.). States may also exert influence over federal activities within the Exclusive Economic Zone, as established by the federal consistency provisions of the Coastal Zone Management Act (16 USC §§ 1451 et seq.). Many of these complexities and overlapping geometries can be seen in figure 2.

Figure 2
Marine regulatory and jurisdictional bounderies in South Florida, US.



In the US, federal and state agencies have a variety of overlapping authorities and jurisdictions. Some of the most important federal players include the US Coast Guard, US Environmental Protection Agency, US Minerals Management Service, US Army Corps of Engineers, and NOAA. This fragmented approach to management of ocean resources at the national level often results in redundant efforts, inefficiency, ineffectiveness, and lack of coordination among agencies with tangled, overlapping jurisdictions. Perhaps more problematic are the unidentified jurisdictional gaps in the existing governance framework that potentially can hinder effective ocean management. These factors emphazise the need for the development of regional spatial frameworks such as the OPIS, which will help make sense of offshore jurisdictional complexities.

Issues Associated with Creating Georegulations

Clearly, there is a need to sort out the policy quagmire, and geography provides an excellent organizing framework for doing just that. The reality of the situation is that very few of the US regulations were written with modern mapping technology in mind. It is not uncommon to find incorrect, imprecise, or inaccurate boundary co-ordinates published in the US Federal Register and US Code of Federal Regulations. Such instances may be the result of simple human error or misinterpretation of ambiguous legal language, or they may be the result of a lack of understanding of mapping principles and technologies. Many times, fundamental cartographic concepts such as scale, resolution, datum, and projection are not considered. In a paper cartographic world, many of the inaccuracies associated with mapping a feature are masked by the scale and width of that feature. Within a GIS these errors can be revealed. And because digital mapping technologies enable the development and visualisation of extremely precise maps, it is essential that those who develop policy understand these important concepts so that the geographic representation of the legal information is accurate.

Examples of mapping ambiguities include listing co-ordinates without reference to a vertical or horizontal datum, referencing ambulatory features such as the "wash of the waves at high tide," "following the 100 fathom isobath," or using language such as "200 nautical miles from the baseline." In the case of this last example, is the correct boundary 200 miles over the surface of the earth, a chord projected through the earth, or some other interpretation of the appropriate algorithm? Many legal descriptions do not give complete information to accurately map the boundary and require the user to be both cartographer and detective. Offshore maritime boundaries are often referenced by their distance seaward from a baseline. A normal baseline is comprised of a series of points along the line of ordinary low water along that portion of the coast that is in direct contact with the open sea and is interpreted by the US to be the same as the mean lower low water (MLLW) line (Thormahlen, 1999). However, because coastlines vary from smooth to deeply indented and are interrupted by bays and river mouths, and because the designation of offshore boundaries may confer significant economic rights, establishment of baselines is often complicated and contentious. A number of rule-based spatial determinations are used in such cases. These aid in establishing closing lines across the mouths of bays and rivers, and help determine the baseline status of islands or intermittently exposed features fringing the shore. The revenues tied to the resulting lines make each baseline point of extreme importance. The financial consequence of baseline decisions is evident in the US Supreme Court case of *United States of America v. State of Alaska* (1975), and the issue of "Dinkum Sands." At issue was whether this small formation just off the northern coast of Alaska qualified as an island with baselines from which a 3 nautical mile Submerged Lands Act Grant would belong to the state. Important oil and gas reserves were discovered nearby and both the US government and the State of Alaska sought the right to grant leases for exploration of the area. After 17 years of legal action, the Court sided with the federal government, establishing its right to the $1.6 billion in oil and gas revenues. This illustration provides significant evidence that geography does matter.

In the US a number of factors complicate the mapping of baselines. As with mapping all coastal and ocean features, the tidal influences on marine boundary elements are considerable. The major complication with US baselines is that there are at least two separate interpretations[3]. Regulatory limits defined by the Submerged Lands Act and Outer Continental Shelf Lands Act for minerals leasing purposes are under the responsibility of the Minerals Management Service. The baseline from which these limits are measured is often ambulatory, unless immobilised under a joint motion by the US Supreme Court (Thormahlen, 1999). NOAA is charged with the responsibility of maintaining the legal maritime boundaries, designated by the Law of the Sea, which delineate sovereign rights, and other rules of international law relating to innocent passage, transit passage, sea lanes passage, and protection of the marine environment (LOS, 1997). These boundaries are measured from an ambulatory baseline and may or may not be coincident with the Minerals Management Service baseline. In other words, one baseline is used for determining offshore revenue sharing and the other is used for determining state, federal, and international sovereignty. The position of each line often depends on the placement of the other in relation to the baseline. Attempts to encode the baselines and the resulting boundaries can result in confusion for the geospatial data community.

Another example of regulatory and mapping complexity can be illustrated by the need for a 3 dimensional component as in the case of the group of islands off the coast of southern California, known as the Channel Islands. The US National Park Service (NPS) has exclusive jurisdiction over the islands (land) and shared administration, from mean high tide out to 1 nautical mile (water), with the National Marine Sanctuary Program managed by NOAA as well as the State of California's Fish and Game Department. Within the 1 nautical mile buffer, National Park Service administers the surface waters while NOAA and the state manage the area below the surface. The state and NOAA share jurisdiction out to 3 nautical miles (seaward state boundary), and NOAA has total jurisdiction out to the National Marine Sanctuary boundary at 6 nautical miles. Not only is the term "mean high tide", used in the legal description, not an actual tidal datum, but the inclusion of

3. In addition to the two federal baselines (fixed and ambulatory), individual states often have their own interpretation of the baseline.

a vertical (surface waters) jurisdiction requires that the representative cadastral boundary be 3 dimensional. This example is difficult to understand and map and complex to manage with regard to the resulting institutional responsibilities.

Another mapping problem can be highlighted by examining the set of demarcation lines that have been established by the Convention on the International Regulations for Preventing Collisions at Sea, 1972 (commonly called COLREGS). COLREGS define boundaries across harbour mouths and inlets for navigation purposes. If a vessel is landward of the COLREGS line, it must adhere to the Inland Rules of Navigation established under the Inland Navigation Rules Act (33 USC § 2001 et seq.). Seaward of the COLREGS line, vessels are subject to rules of navigation established by the International Regulations for Preventing Collisions at Sea, as amended (33 USC § 1601 et seq.). Historically, the COLREGS lines have been established by drawing a line across a harbour mouth on a paper nautical chart. In addition, geographic references that position these lines are published in the US Federal Register. However, these references typically include no co-ordinates and, furthermore, often reference ambulatory or ephemeral geographic or manmade features. The georeferencing methods used to describe the location of the COLREGS line are all too often insufficient for use within a digital mapping environment. For example, the following language is used to describe a section of the COLREGS line running from Tybee Island to St. Simons Island, Georgia. "A line drawn from the southern most extremity of Savannah Beach on Tybee Island 255° true across Tybee Inlet to the shore of Little Tybee Island south of the entrance to Buck Hammock Creek" (USDOT/USCG, 1995).

As evidenced by these few examples, creating actual digital spatial map layers for use in GIS and Electronic Nautical Charts (ENC) is often problematic. In many cases, the legal description of the boundaries may not adequately describe the geography or it may be extremely complicated, requiring subjective interpretation. New legislation and regulations must take into consideration the state of mapping technology. Ideally, the policy regime will list the bounding co-ordinates and metadata (*e.g.*, datum) with enough precision to adequately create the spatial data layer. Removing the ambiguities is a necessary component to reduce uncertainty for resource analysis such as may be done in GIS or for safe navigational uses in ENC applications.

The Ocean Planning Information System

This effort to outline the policy framework is part of an ongoing project to develop an Internet-based ocean governance and management GIS to facilitate the shift in the US from fragmented management of individual ocean resources to a more integrated, region-wide management approach. The Ocean Planning Information System (OPIS) Web site was developed utilising Environmental Systems Research Institute's (ESRI®) MapObjects™ Internet Map Server in conjunction with Visual

Basic®, JavaScript and Hypertext Markup Language (HTML). Major features of the site include an interactive mapping application (see fig. 3), marine and coastal spatial data and download tools, associated metadata, and legal summary pages, all designed to support regional ocean management.

The project is targeted at the individual southeastern coastal states and allows the ocean resource manager to examine the significant issues and data of the region in conjunction with the supporting text that describes the laws. The system supports analysis from a particular area of regulated interest, such as marine plastics disposal, or from spatial analysis such as a particular geographic location (*e.g.*, point on the map). Standard GIS functions are supported, such as view, change layer, pan, zoom and query. The unique element in this project is the linkage between the policy and its geography. Each applicable data layer contains an attribute link to the appropriate legislation. Using the power of HTML, the attribute is linked to the text version of the legal description.

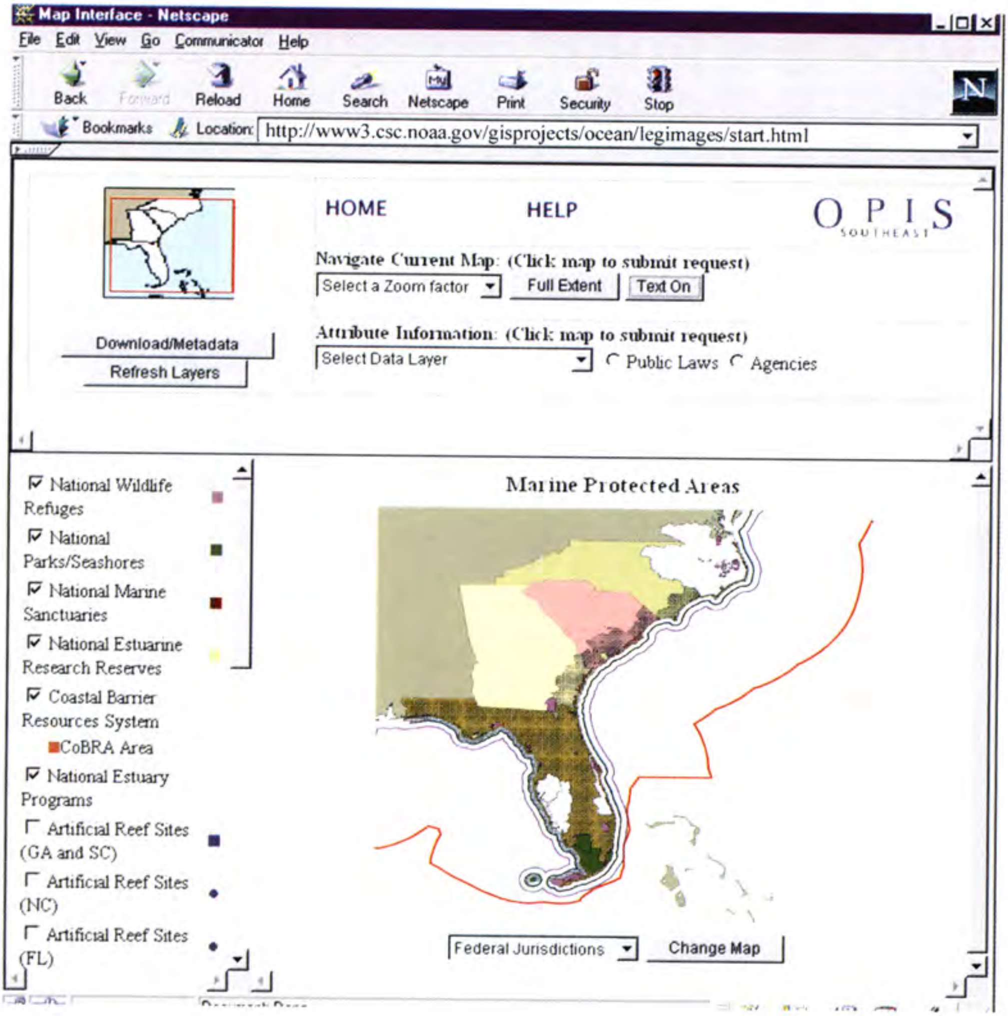


Figure 3
The Ocean Planning Information System (OPIS) Internet mapping application.

The user clicks on the map area and is presented with the legislation or agency information associated with that particular point. The flexibility of Internet mapping technologies allows the user to successfully "drill down" to the level of detail needed to satisfy the analysis. For example, the user can look at the attributes of a feature or list the names of the federal regulations related to the point. He can pick a particular act and look at a synopsis of that legislation or he can link to the actual US Code of Federal Regulations for more information. In this example, the user would start with the description of a particular piece of legislation and then look at the data layer associated with the act to see what the spatial extent is and what resource features may be impacted.

Conclusions

Spatial analyses of ocean policy can provide an important component in balancing the conflicting uses of resources that are occurring in our planet's oceans. Tools such as GIS can help policy makers identify gaps and overlaps in regulations. These types of decision support tools can lead to better management decisions and more integrated ocean management strategies. In order to conduct the necessary analyses, spatial deficiencies of policy and management regimes must be identified and addressed. New regulations must consider the state of the technology and adequately describe the geography under consideration. Where possible, federal agencies must clear up ambiguities in legal descriptions. The OPIS prototype is an example of what can be accomplished when this is in place. The Ocean Planning Information System Web site can be accessed at *http://www.csc.noaa.gov/opis/*.

Bibliographic references

Graber P.H., 1980. The law of the coast in a Clamshell. Part 1: Overview of an interdisciplinary approach. Shore and beach. October 1980.

National Research Council (NRC), 1997. Striking a balance: strengthening marine area governance and management. Washington, DC, National Acad. Press.

Thormahlen L., 1999. Boundary development on the outer continental shelf. US department of the Interior, Minerals Management Service, mapping and boundary branch, technical series publication, MMS 99-0006.

United Nations, the law of the sea (LOS), 1997. The United Nations convention on the law of the sea with index and final act of the third United Nations conference on the law of the sea. New York.

US Department of Transportation, US Coast Guard. 1996. Navigation Rules: International — land. COMDTINST M16672.2C, Washington, DC, US Government Printing Office.

Problems with definitions and meaning of some elements in a GIS for the management of regulated coastal areas

José L. Sanz, Ana B. Lobato, Olvido Tello.

Instituto Español de Oceanografía (IEO), laboratorios centrales, C/Corazón de María 8, 28002 Madrid, España - josel.sanz@md.ieo.es

Abstract

The Instituto Español de Oceanografía and General Secretary of Marine Fishing are developing a marine GIS whose objective is better knowledge and management of the coastal zone (mainly marine reserves and mollusc production areas) and regulation of fishing activities through laws and the construction of artificial reefs.

It involves gathering information on legislation, geographical and administrative boundaries, as well as the environmental characteristics of the marine areas. However the information is extremely inconsistent due to the multiplicity of sources, different research objectives, conflicting definitions of administrative boundaries, as well as the different meanings for the same element.

This paper presents the main problems encountered in developing the SIGMAZAL project on the Spanish continental shelf and the solutions adopted.

Résumé

L'IEO et le Secrétariat général des pêches maritimes (SGPM) sont en train de développer un SIG marin afin de faciliter la connaissance et la gestion de la zone littorale (zones de réserve marine et zones de production de mollusques) et la réglementation de la pêche par l'élaboration de lois et la construction de récifs artificiels.

Tout ceci implique de réunir des informations sur la législation, les limites géographiques et administratives et les caractéristiques de l'environnement marin. Mais l'information présente de graves incongruités à cause de la multiplicité de sources, des divers objectifs des recherches effectuées, de la mauvaise définition des limites administratives et de la difficulté d'interpréter les différentes significations d'un même élément.

On présente dans ce travail les principaux problèmes rencontrés pendant le développement du projet et les solutions adoptées.

Introduction

The Instituto Español de Oceanografía (IEO) and the General Secretary of Maritime Fishing (SGPM) from Ministry of Agriculture, Fishing and Food are currently developing the SIGMAZAL (Geographical Information System of Coastal Conditioning Areas) project (Sanz *et al.*, 1997). The scope of the project is to prepare a GIS, which will make appropriate management and monitoring of the Coastal Regulated Zones by the Administration possible, in order to protect and regulate anthropogenic activity in some Spanish continental shelf marine areas of economic and biological interest (SGPM, 1995).

These actions require that areas be specifically set out for marine reserves (SGPM, 1999), artificial reefs, hulls sunk to make artificial reefs and protection and production of molluscs (SGPM, 1996). To date, there are enough areas with the above mentioned characteristics (SGPM, 1995, 1996, 1999), but they are not managed and monitored in a homogeneous way.

This GIS will provide the Administration with a tool providing the environmental conditions of given areas, their features, the degree to which laws are enforced and the development of Sector Plans. To answer these requests, the GIS should incorporate not only marine environmental information, but also information on the coastal area (rivers, lithology, topography, etc.), the results of the studies carried out by the Administration in the regulated marine areas and legislation concerning them.

The project has been developed in three stages:

- resource analysis, assessing GIS needs and designing its structure;
- collecting and inputting information and implementing results in a pilot area;
- developing the GIS on the Spanish continental shelf. The project is currently in the third stage.

The conceptual structure of the SIGMAZAL project (fig. 1) was designed following analysis and definition, together with the final user, of:

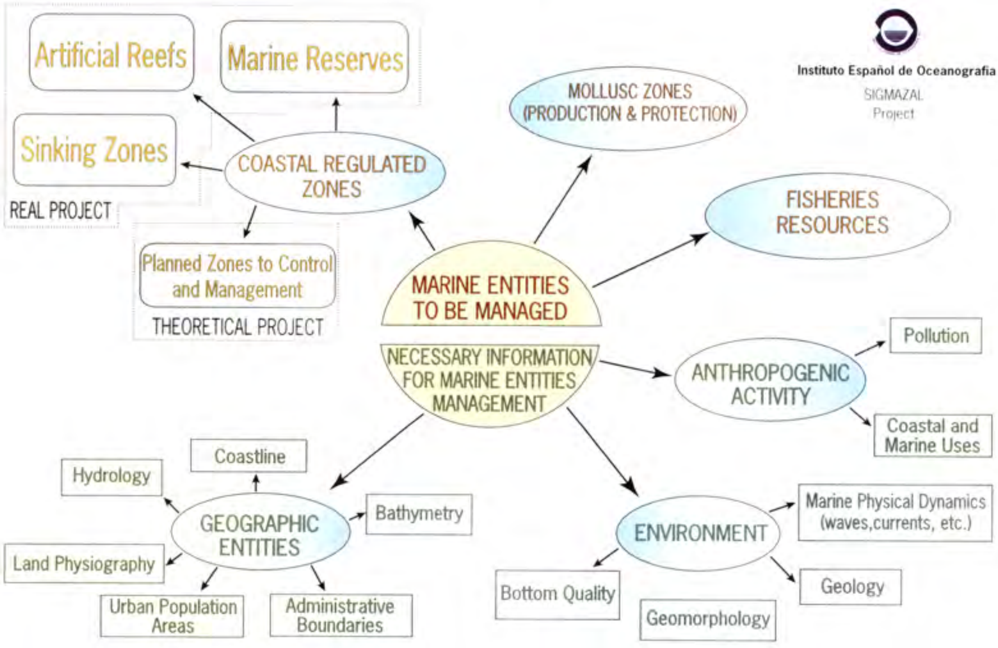
- objectives to be covered by the GIS;
- priorities in the different fields;
- identification of the features which should be in the databases (DB).

This led us to define the necessary elements and coverages to describe the marine environment, to determine the characteristics of attribute tables, graphic features and the classes or values that the variables (or fields) should have.

Identifying and defining the elements was quite complex. Final users (the administration drawing up the law) did not consider every regulated zone as part of a larger universe, they had not uniformly defined the information layers (not even on paper) and they used confusing terminology (the same name for different elements).

We concluded that the final users knew the problem well, but had difficulties in conceptualising and formulating it in terms of relevant geoinformation. Consequently, it was necessary to make a dictionary defining the basic elements before developing a conceptual structure. However, the main problems in developing the project have been:
- conflicting interpretation of the legislation on regulated marine areas, due to vague wording and georeferencing errors;
- the existence of several coastlines;
- the diversity of sources of environmental information and the quality of data (contradictory and heterogeneous information);
- definition and description of elements that could be misinterpreted.
These problems and some of the solutions adopted are analysed in the following sections.

Figure 1
Conceptual structure of the SIGMAZAL project.



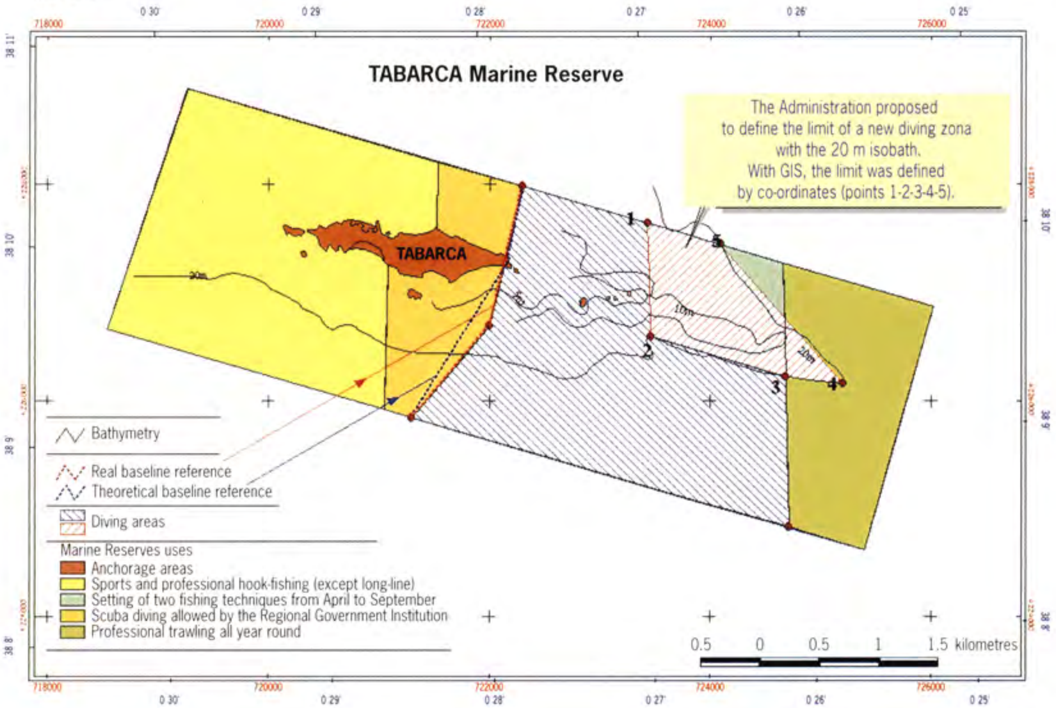
Vaguely worded legislation

In the legislation, the definition of the boundaries of regulated marine areas (marine reserve, artificial reefs, protected fishing grounds, etc.) does not often refer to co-ordinate, but is rather associated with features (fig. 2) such as depth (although it changes over time, with storms, etc.), points on the coast defined by toponyms, distances to the coast (which shifts), etc. However, none of these features are georeferenced or clearly defined.

On the other hand, when the legislation describes the boundaries of the marine areas using co-ordinates, it rarely indicates the datum or the reference map. Although official Spanish cartography is mainly in the European datum 50 (ellipsoid Hayford) (ED-50) cartography also exists in WGS-84, Madrid datum (ellipsoid Struve), pico de las Nieves datum (Canary Islands) and Mercator, UTM and Lambert projections.

It must also be born in mind that in Spain the Central Government legislates the area of external waters and the legal terrestrial-marine demarcation (which does not coincide with the coast), and regional governments legislate in the area of inland waters. There are also several official cartographic services, the Instituto Geográfico Nacional (IGN-Spain), the Instituto Hidrográfico de la Marina (IHM), the Servicio Cartográfico del Ejército (Army Cartographic Service) and other regional cartographic services (autonomous communities).

Figure 2
Definition boundaries with GIS.



This diversity of legislation and of cartographic services working with different objectives, as well as the confusing legal definition of some of the regulated marine areas, mean that, in some cases, the limits of these areas will change from one map to another, and therefore problems arise in incorporating the information in the GIS and in linking geography with laws.

Consequently, it has been suggested that the SGPM use the environmental, scientific, and legal information stored in the GIS and the precision of their tools to define limits for the new areas, as well as to propose a new law with well-defined co-ordinates, for the problematic areas. In the definition, the boundaries of the areas will be described by simple geometry (fig. 2), similar to that of the reference features used (isobaths, seagrass meadows, etc.) with all the points georeferenced in sexagesimal geographic co-ordinates and ED-50.

This decision has been taken for several reasons:

- it would provide better description of boundaries and facilitate ship positioning;
- the position of a point in the sea is usually expressed in geographical co-ordinates and fishermen use these co-ordinates;
- it would be more complex to use UTM co-ordinates, because the Spanish marine area occupies five time zones, zone 27 and 28 in the Canary islands and zones 29, 30 and 31 in the peninsula and Balearic islands area, and two zones include several autonomous communities;
- the information in the GIS should be continuous. The use of geographical co-ordinates avoids the problem of time zone changes in the UTM system and, when it is necessary to work in another system of co-ordinates, it facilitates projection changes.

Where is the coastline?

The coastline is a complex and difficult element to define. Legally speaking, it is an important legal limit for different Administrations and it should be a static element, defined by a line. However, the real coast is dynamic, as a result of environmental evolution.

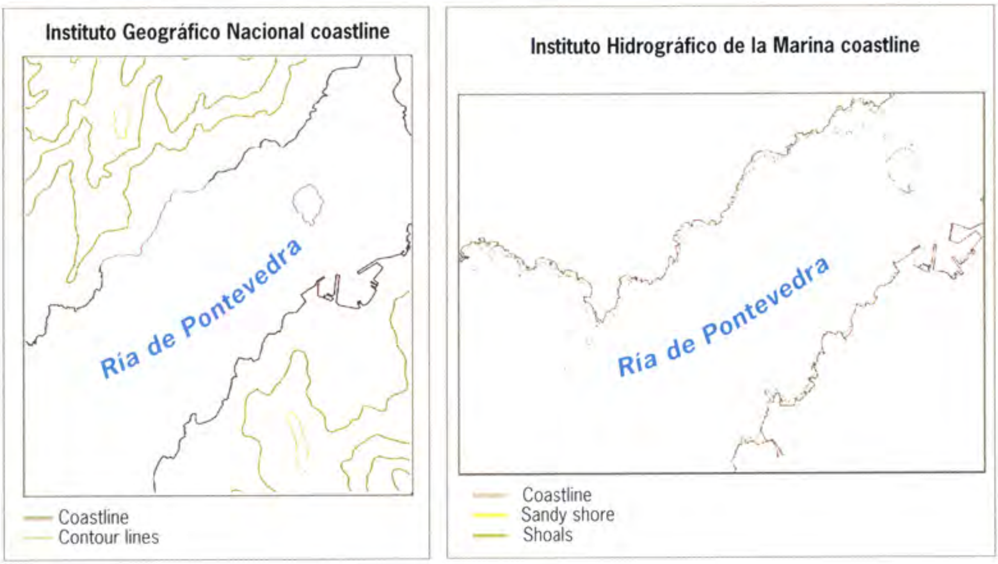
In a GIS for coastal management, the coastline is an important limit and it carries a lot of semantic information (legal, environmental and economic). Therefore, it was the first element to be put into the GIS, but this rose a new critical issue, because official data sources do not coincide. According to the cartographic services used as references (IGN and IHM), the land-sea limit definition differs and the existence of tides complicates this definition. There is also continuity between an area with tides (Atlantic) and another without tides (Mediterranean Sea).

Terrestrial cartography and the official Spanish coastline have been published by the National Geographical Institute (IGN) in UTM projection, but this coastline does not show the intertidal zones. For marine zones, the official cartography is published by the IHM in Mercator projection, but depending on the area, nautical charts have different scales and resolutions and they indicate as land or intertidal areas all zones that potentially emerge and therefore may be a danger for sailing. Consequently, these two coastlines differ in many points (fig. 3).

On the other hand, definitions are lacking for the coastline in areas with tides (in our case the Atlantic and Cantabrian shores), especially if the coast is smooth, because tidal variations and storms displace it a lot. The coast, instead of being a line, should be represented as a polygon, in which important processes are developing. It is also necessary to consider that the coast of the Iberian peninsula has continuity between the Atlantic Ocean (with tides) and the Mediterranean Sea (without tides), and although the transition area is small, the sea level changes greatly with the tide. A solution for this complex situation would be to develop one GIS for the Atlantic and another for the Mediterranean Sea, but the system and the information should be continuous for the whole continental shelf.

Another fact that produces quick and major modifications in the coast is the construction of harbours, buildings near beaches, etc., because they change the marine and sedimentary dynamics. This gives rise to changes in the legislation for the modified geographical space, when a marine area changes to terrestrial or *vice versa*. What happens in these cases? When will it become necessary to update the coastline? Should the GIS have a real coastline and a legal one?

Figure 3
Two official maps, and different coastlines.



The mobility of the coast is a problem to address on detailed scales, because, on one hand it changes the limits of polygons and on another it affects the bathymetry, since it changes the baseline and the depth of the adjacent submerged area. In our case, the working scale is more or less 1:20 000 and isobaths are 2 m equidistant, for depths between 0 and 50 metres.

Thus, it was difficult to decide which coastline should be incorporated into the GIS, and which was the real extension of intertidal areas. The final decision was to consider the coastline as a static element, for the moment, and to use the BCN-200 (1:200 000 scale) of the IGN, Spain as the coastline. This was for three reasons:

- it is continuous;
- most of the terrestrial maps use it as baseline;
- as does marine research in areas closer to the coast.

This coastline will be changed soon by the BCN-25 (1:25,000 scale) of the IGN. Because of the continuous coastal modification, we consider that in future there will be two coastlines incorporated into the GIS, the legal one and the real one.

The problem of the diversity of information sources

The information incorporated into the marine GIS project mainly comes from the SGPM (studies on Marine Reserves and Artificial Reefs) and the IEO (depth, nature of the seabed, fisheries mapping, etc., of the continental shelf), but also from other national (land data, tectonics, morphology, lithology, etc.) or regional agencies (detailed local research). Working rules are different in every institution, sometimes they are somewhat standardised but they use different scales and the studies that they make are concentrated in specified areas or focus on a specific scope (seeking areas to remove sand for coast regeneration, studies on beach stability, etc.), and they do not standardise the collection, management and organization of related information, which is important afterwards. Moreover, as there is no generally accepted nomenclature, maps and reports on an area have class divisions which are almost impossible to homogenize.

For this reason, the information collected does not have spatial, temporal or class continuity, and therefore the results of studies and research by different authors on the same area are usually difficult to correlate. Objectives are also different, as well as the precision in collecting data, the scale of analysis and the meaning or the interpretation of the same element.

Therefore, in most cases the information gathered should be synthesized and filtered or even reinterpreted (homogenizing it and adapting it to the SIGMAZAL project objectives) according to the elements, classes, coverages and tables previously defined in the conceptual structure.

We also concluded that final users (the administration mainly) did not consider each project as part of a larger whole, nor did they have uniformly defined information layers. As a result, it was necessary to prepare a document with the standards for studies to be carried out by SGPM thereafter.

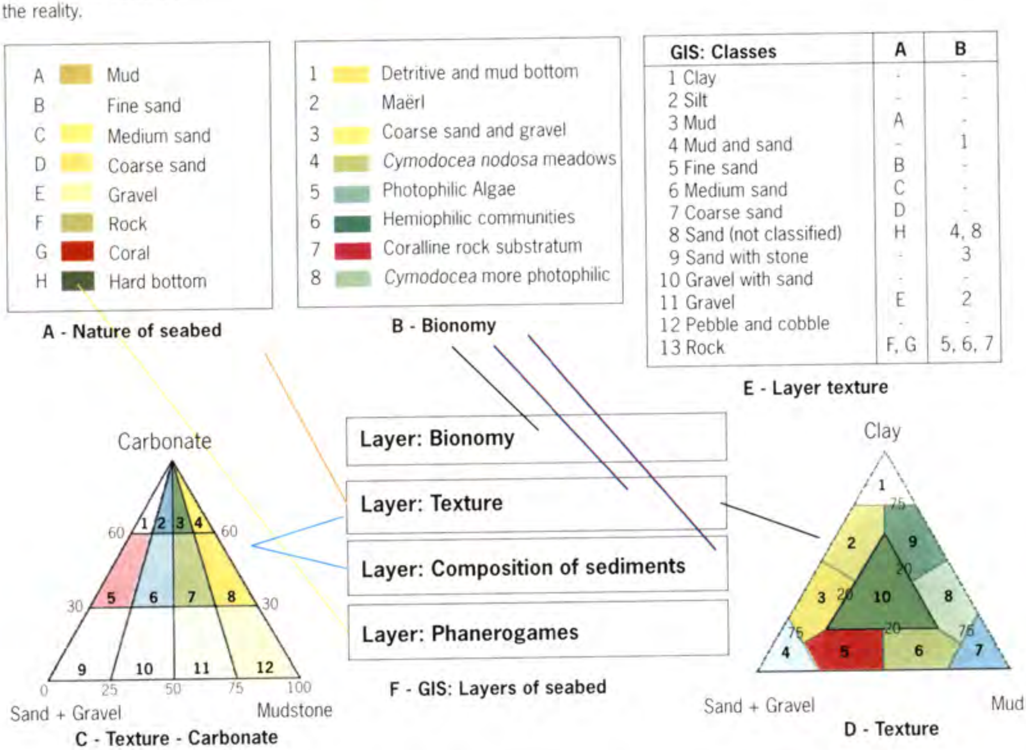
Difficulties when defining classes or values in some information layers

The meaning of some elements varies according to the observer's point of view (ITGE, 1990; Ballester *et al.*, 1999). Thus one main difficulty has been to determine the best classes defining the seabed, which depends on the objectives of the study and of the specialist carrying it out (the interpretation and classification of each phenomenon will be different for a biologist, a geologist or an engineer). Although there are commonly accepted classifications (Krumbein, 1938; Folk, 1954, Shepard, 1954; Meinesz *et al.* 1983), the definition of the seabed can vary considerably in accuracy or in type (lithology, granulometry, mineral composition, bionomics, geophysical response, etc.). Besides, several classifications can be combined, or a classification with only a local value can be used.

For example, a seabed of calcareous sands coming from the breaking up of mollusc shells, with ripple areas and with a receding meadow of *Posidonia oceanica* (a zone in which rhizomes make up a hard bottom), can be classified on different maps or reports according to granulometry, composition, genesis, bionomy, marine dynamics, etc. But the relationship between an element and its environmental meaning is not a commutative property, and thus, the presence of a hard bottom does not always mean that there is a receding seagrass meadow. How can it be classified when it has more than one meaning?

Therefore, on each map, the variety of possibilities gives rise to the generation of different polygons in accordance with the criteria used in the classification of the seabed and the classes it has been divided into (fig. 4 A, B, C, D).They depend on the scale of the maps, the measurement precision, etc. Moreover, the classifications frequently mix different concepts (fig. 4 A, C) and/or include classes that can be misinterpreted (*i.e.*, hard bottom).

In consequence, it has been quite complex to define information layers and classes to describe the nature of the seabed. We had to interpret the meaning of different information, to define several information layers divided in homogeneous classes to distribute the information from the most frequent classifications (fig. 4 E, F).



GIS: Classes	A	B
1 Clay	-	-
2 Silt	-	-
3 Mud	A	-
4 Mud and sand	-	1
5 Fine sand	B	-
6 Medium sand	C	-
7 Coarse sand	D	-
8 Sand (not classified)	H	4, 8
9 Sand with stone	-	3
10 Gravel with sand	-	-
11 Gravel	E	2
12 Pebble and cobble	-	-
13 Rock	F, G	5, 6, 7

Figure 4 (A, B, C, D) Classification of the seabed in several maps of the same area from different points of view and scales. (E) Classification of A and B in the GIS. (F) The interpretation of the maps allowed to split information into GIS layers and to better define the reality.

Thus, the information received from the real world is complex and seeing the extensive and varied geographic area covered by the SIGMAZAL project, the meaning of each new piece of information must be interpreted correctly. On the other hand, we had to increase the number of fields associated with the seabed element and to reinterpret a part of the information loaded to the system (fig. 4 E), as new elements or classes have been identified over time. This has provided better definition of the environment and makes it possible to use the information for different objectives, as it is broken down further.

Conclusions

The experience with the SIGMAZAL project has shown that:

• Although official institutions and scientific investigation groups carry out many studies with the purpose of contributing to better marine resources management, the objectives of the investigations vary greatly, because:

- the ranges of their areas of interest are very variable;
- they do not have common standards;
- they do not have the same minimum information layers nor the same classes associated with each level of information.

The regulated marine areas should be well-defined by the law, using static criteria and indicating the co-ordinates and the reference system.

• The definition should use the information stored in the GIS and the precision of its tools. The reference elements (isobaths, limit of seagrass meadows, etc.) will be simplified and they will be described using simple geometry, close to real features (polygon, line or point), with the points georeferenced in sexagesimal geographical co-ordinates.

• The coastline chosen at this stage has been the most continuous and detailed. It will be the legal coast in the future, when the coastal modifications are incorporated into the GIS. Therefore, there will be a real coast and another corresponding to an administrative limit.

• The use of a GIS tool has allowed us to detect errors in the geographical definition of some project areas, as well as in some of the boundaries already established by the government law bulletin BOE 234/1977 (1977).

The lack of clear standards in the research and monitoring carried out by the administration in the regulated marine areas hinders their comparison, because the levels of information are different.

• The development of a GIS for coastal management is subject to consecutive changes and to progressive adaptations of its structure, because the users' needs and requirements change over time.

The above difficulties should urge the setting up of a special group to discuss the reference data at national level, as well as to develop standards in the working methodology in studies on coastal areas.

Bibliographic references

Ballester R., Calvín J.C., Vicente M., 1999. La cartografía bionómica como herramienta básica para la creación y gestión de reservas marinas en la región de Murcia. Proceedings 1st international workshop on marine reserves, Murcia, Spain, 57-58.

BOE, 1977. Real decreto 2510/1977. Sobre definición de aguas jurisdiccionales y lineas de base recta. Boletin oficial del Estado 234.

Folk R., 1954. The distinction between grain size and mineral composition in sedimentary rock nomenclature. J. Geol., 62, 344-359.

ITGE, 1990. Mapa geológico de la plataforma continental española y zonas adyacentes. E. 1:200 000. Memoria y hoja, 79-79E. Murcia. Servicio de publicaciones del Ministerio de Industria y Energía. Madrid. (definición de clases de facies).

Krumbein W.C., 1938. Size frequency distributions of sediments and the normal phi curve. J. Sediment. Petrol., 18, 84-90.

Meinesz A., Boudouresque C.F., Falconetti C., Astier J.M., Bay D., Blanc J.J. *et al.*, 1983. Normalisation des symboles pour la représentation et la cartographie des biocénoses benthiques littorales de Méditerranée. Ann. Inst. Océanogr., Paris, 59(2), 155-172.

Sanz J.L., Lobato A., Acosta J., Herranz P., 1997. The SIGMAZAL project. A marine geographic information system. Proceedings of the 18th ICA/ACI International Cartographic Conference, Stockholm, Sweden, 4, 2271-2275.

SGPM, 1995. Documento sobre las zonas marinas protegidas. Internal report. Secretaría general de pesca marítima, Ministerio de Agricultura, Pesca y Alimentación, Madrid.

SGPM, 1996. Zonas de producción y protección de moluscos. Internal report. Secretaría general de pesca marítima, Ministerio de Agricultura Pesca y Alimentación, Madrid.

SGPM, 1999. Zonas de reservas marinas. Internal report. Secretaría general de pesca marítima, Ministerio de Agricultura, Pesca y Alimentación, Madrid.

Shepard F.P., 1954. Nomenclature based on sand-silt-clay ratios. J. Sediment. Petrol., 24, 151-158.

Conclusion

Coastal GIS at the turn of the century

Darius Bartlett[1], Cindy Fowler, Roger Longhorn, Francois Cuq, Lionel Loubersac

(1) University College, Department of Geography, Cork, Ireland
djb@ucc.ie

The final session of CoastGIS'99 took the form of a panel discussion, led and chaired by Darius Bartlett with contributions from Cindy Fowler, Roger Longhorn, Francois Cuq, Ron Furness and Lionel Loubersac. This was followed by a wider discussion of topics and issues raised, and included several interventions and commentaries from the floor. What follows is an edited transcript of the main points raised. While based on the verbal contributions from those named, editorial responsibility rests entirely with the session chair.

Darius Bartlett

Several interesting themes have come out of this conference, of which the most significant are probably those relating to coastal data. This topic has been addressed from a number of perspectives, and speakers have examined definitions of data: semantics, the design and use of data dictionaries, semiotics (that is the symbolism or meaning) of data; and also metadata and standards. Clearly these are all areas where there is much research activity, and where a lot of peoples' thinking is focused at the moment.

Related to the foregoing, a second important topic raised in many presentations has been the question of interoperability. This concept extends well beyond the technical dimension, and several other types of working together were discussed. For example we heard about institutional interoperability, that is helping institutions and people interact. This is a particularly important issue because, amidst our many and diverse professional or disciplinary interests, the one thing we all share is a concern with integrated coastal zone management. We may approach the issue from different starting points but, if we are to achieve this integration, somewhere along the line we have to find ways of getting all the different interest groups and stakeholders at the coast talking the same language. In other words, we are looking at, or for, interoperability at the level of the personnel involved, and also interoperability of the data we are collecting and using. A number of presentations and discussions addressed this last, particularly through examination of data exchange standards.

Wider contexts

These discussions and issues also mirror events taking place in the evolution of GIS generally. The whole field of GIS appears to be undergoing rapid change and evolution at the moment, both technologically and institutionally, though at least some of these changes almost suggest a return to earlier ways of doing things (in some cases, more efficiently in the light of technical improvements) rather than the introduction of radically new methods and techniques. For example, in the early days of Arc/Info and other pioneering proprietary systems, GIS software was often packaged as a "toolbox", with a wide array of utilities and functions provided with the system, but as separate modules, so that the user could select the specific tools required for a particular task and apply these as required. Later on came the more integrated approach, where all possible tools and functions were provided within a single package, with a common interface, whether they were required or not. This meant that users were inevitably stuck with the weaknesses of whichever GIS product they had selected, as well as its strengths. For coastal GIS this has been particularly relevant, since (as is often asserted) almost all commercially-developed GIS have been designed and optimised for handling terrestrial rather than coastal or marine data; thus, the coastal GIS user was more-or-less forced to use tools and techniques that were inherently weak for the specific application(s) concerned.

In recent years, we have seen a move back towards the toolbox approach to GIS, this time based on a "plug and play" concept. The bricks in a child's "Lego" set offer a good analogy: in a "Lego" set, we find many general-purpose bricks, and also a smaller number of more specialized components. Whether generic or more specific, each piece has been designed to facilitate easy interconnection and, in this way, can be assembled so as to create whatever model the child wishes. Similarly, emerging standards of interoperability are encouraging software developers to create application-specific modules that "plug into" a core set of generic GIS functions. Thanks to this new approach, people will likely soon be able to select and assemble their own custom-built geoprocessing system from tools that best suit their specific needs and applications (in practice this assembly will often be undertaken for the end-user by specialist consultants or other intermediaries who are expert in system selection and interfacing). Some of the elements in these custom-built systems may be unorthodox by today's standards but, by integrating them within a single coherent framework, we will be able to harness the synergy of their interaction, and turn these separate tools (including many elements of existing GIS) into dedicated and specialized coastal information systems. A number of the presentations made at this meeting have reflected this evolution, and we already can see clear benefits, in terms of utility and flexibility of such approaches.

Making GIS more user-friendly

On the wider stage, there has been much discussion, and development effort, devoted to making GIS more user-friendly. The means of achieving this has been a frequent topic for debate in many GIS-related meetings and on-line discussion groups in recent years. The main concern here is to make GIS more accessible and thus optimise effective GIS use, because GIS is still often seen as being very complex. While these are important matters, are we approaching the problem from the right direction? Should we be trying to make GIS more user-friendly? Perhaps we should accept that GIS will always be inherently complex, since the systems are designed and developed to help us manage geographical complexity, and instead concentrate on providing appropriate training and education for users, in order to better equip them to use the technologies available. If not carefully thought-out and executed, enhancing user-friendliness could run the risk of coming perilously close to a "dumbing down" of GIS.

Institutional questions

We also need to consider the type of role that GIS is expected to fulfil within an organization, because this is yet another area where changes seem to be in progress. If we look at the early years of GIS, most of the pioneering systems tended to fulfil one of two primary functions, namely the digital production of maps on the one hand, and adding spatial search and retrieval functionality to databases on the other. In many contexts, GIS is still used for digital cartography, or as a means of storing, retrieving and displaying data using geography as the primary search mechanism. However, there is a move now beyond such uses, towards more integrated and advanced decision-support systems, where the GIS is actually helping decision-makers plan strategies and undertake other policy-making tasks. Going even beyond this important step, there is evidence that GIS is becoming increasingly adopted as part of a much wider scientific research methodology: this was particularly demonstrated in a number of presentations from our French colleagues at this meeting, where we saw GIS being used as an aid to better understanding of coastal processes, and other phenomena.

Standards

Somebody once said, rather cynically perhaps, that "the nice thing about standards is that there are so many to choose from"! We have heard much discussion here about standards. We were told how the researchers were faced with a choice between American and European standards for metadata, and in the end decided to take a hybrid. While it is all too clear why such a decision might be taken, one also wonders whether a hybrid between two standards is not rather defeating the purpose of having these standards in the first place? If the standards are not good enough, then perhaps they need revisiting and reassessment or revision. That is another question, but if we have standards, we should make every endeavour to adhere to them.

E-commerce

One thread which surprisingly has not been in greater evidence here is the whole idea of electronic commerce. It is an issue that is becoming more and more important, and surely it applies just as well to coastal data. The implications of using coastal data as a marketable commodity are issues that need to be considered as a matter of some urgency. The closest we came to discussing these important questions was when the movement or flows of information were touched on by a couple of speakers.

In this latter context, it seems worthwhile to suggest the metaphor of "data ecology". The name, and the imagery it evokes, are appropriate: in ecology, you have primary and secondary producers, you have different trophic levels, consumers and so on, and you get conversion and enrichment in the process. We do also have primary and secondary producers of data, and consumers of data, and so on. Couldn't this be an alternative way of looking at the circulation and use of data and information in our society?

The World Wide Web

Everyone is talking about the Web these days: it is a bandwagon that we all appear to be leaping onto for fear of being somehow left behind. In the process, we are investing a lot of time, effort and money in our endeavours, but are we adequately future-proofing our investments? Is the Web sufficiently mature (both as a concept and as a technology) for us to place so much reliance on it? There might be great potential danger in us all going so rapidly and eagerly down this one particular path, without leaving an "escape route" in case the bubble bursts?

Extending GIS

As far as applying GIS to the coastal zone is concerned, I think we all now accept that current technology is making definite inroads towards solving many problems, but equally there remain many issues still unresolved. As alluded to above, very few GIS are genuinely optimised for coastal, let alone, marine applications. It is surely worthwhile looking at the several alternative technologies available, or emerging in GIS, and consider how - if - they could offer solutions to some of these issues, and advances over our current ways of doing things. These alternatives include Cellular Automata, Voronoi Tessalations and related data structures, Genetic Algorithms and Virtual Reality (VR). This last, in particular, undoubtedly represents a technology of the longer-term future, but sustainable coastal management could benefit enormously from the successful and imaginative application of VR. If it is physically impossible to access a lot of the coastal zone, perhaps VR could "take us there" instead?

GIS is dead: long live GIS!

Someone in another context was suggesting that possibly GIS will have really "arrived" when it is so common place that we don't need to call it GIS any more; in other words when it is taken for granted that we are using GIS where such techniques are called for. We have still a fair way to go, but already some of the larger general-purpose software vendors are now producing off-the-shelf products that to all intents and purposes are GIS, even though the end user may not recognize the fact. This move towards embedded, ubiquitous GIS - such as are represented by in-car navigation systems - carries several important but, as yet, largely uncharted implications (and possible opportunities) for the coastal GIS community, and would merit careful monitoring and periodic analysis.

And finally...

As a closing observation, it may be noted that people tend to see "GIS" as Geographic Information Systems, with the emphasis on GIS as a tool. This is an issue frequently raised by a growing number of authors. For many, this "utilitarian" definition of GIS is restrictive and excessively narrow in focus. Instead, it is suggested that we should be decoding the acronym "GIS" as referring to Geographic Information Science, of which the process of automating the handling of geographic information is part, but only part, of the equation. This alternative definition surely receives much support when we consider the contents of many of the papers presented at this CoastGIS meeting, which show clearly the use of GIS not only as a tool but - as previously alluded to - as a distinct element in any scientific methodology. On this score, we should particularly commend those presenters who have included flow diagrams and "organigrammes" of their thinking in their papers. By capturing and presenting the thought processes and logical steps they have gone through, they underline that they are using GIS as a way of conducting science, for mining data for information, asking questions, and getting answers.

Cindy Fowler

Working in the coastal zone, we really have some unique problems that our land-based colleagues do not have. This land-water interface really complicates our lives. We have multiple agencies coming together, we have the history, the evolution of the mapping in the water with the mapping on the land. Trying to make those two come together in the coastal zone is very complex. There are three topics that should be addressed here, namely research and technology, legal implications and, lastly, lever aging information from the navigation community. This last is important, because they also have some similar databases that we need to work on.

Research and technology

In the area of technology, we still need to find data structures that can really address the 3D and 4D environment. We really need to push the research in that area, so that we can start looking at the water column, and at various temporal aspects of the coast such as tides and water movements. We can see that several system vendors are starting to respond to such needs: for example, the overall theme of the last ESRI user conference was "Ocean GIS", and the company gave the clear message that it is paying close attention to the coastal and ocean regions as an important marketing area. Hopefully, their interest (as well that of other vendors) will lead us to some different data structures and software to model this offshore area.

Then, there is the whole question of numerical modelling of the environment, rivers and streams and hydrology, an approach which is not yet very well married with GIS. Progress in this area has been very slow over the last 15 years. There will hopefully be a conference, coming up next year, on this theme of integrating environmental modelling with GIS.

Legal issues

As far as legal applications are concerned, a number of papers presented here have addressed the legal implications of, and frameworks for, applying GIS to the coastal zone. We are just covering some of the issues involved, and we have a long way to go. Our politicians, policy makers and lawyers are hardly paying any attention to such matters at present, and this is disturbing. In the United States, a lot of new legislation is being enacted without really looking at the impact of technology in the areas covered by these laws. We still have a lot of research, and also lobbying, to do in this area.

Navigation

Because hydrographers have been charged with mapping for safe navigation for so many years, many of our primary data sets (bathymetry, and also mapping of shorelines and other ocean features) come from this community. The hydrographic profession is starting to organize internationally, their products are becoming much more standardised, and they are starting to look at the overlap between access to data and use of these data in GIS and other applications. But members of the hydrographic community also tend to have a bias towards the shore, which suggests they are reluctant to pay attention to anything that doesn't impact directly on information needs for navigation. Thus, while they may collect wide-ranging data in the field, when it comes to creating their archives and databases, they are liable to throw away any bathymetric data that are not seen as relevant to their immediate needs. If the hydrographer is looking for shoals, for example, or other places that someone run aground, data relating to canyons or to a deep area of sea may often be thrown away; or, in a case of a shoreline, data update may not happen if the shoreline is eroding, whereas it would be more likely if the shore was accreting. And yet these are also basic primary data layers that we need in the coastal zone for use by a much wider community. Since the money is clearly there to create the data sets for navigation purposes, we need to try to make their creators look at the broader picture, and remove the biases, so the data may acquire added value.

Roger Longhorn

Metadata

The coastal community is often not aware that the CEN/TC 287 committee completed all of its GIS-related standards over a year ago. The committee is actually wound up. The drafts of the standards have all been published, and are with the national standards bodies, though most of these bodies are not implementing the standards because they only are draft agreed standards, not mandatory ones, mainly because ISO was also producing standards in roughly the same areas.

What is still missing, though, is having a much higher level, a top level, of standards information, that enables us to find data more easily. And the only real standard that is coming in this latter area is not being pushed from a standards body at all. It is coming from the Dublin Core working group (named after Dublin, Ohio). We are trying to get an initiative going now, using Dublin Core "read data" fields to get into GIS, and geographic information generally, and we need to move that into the coastal zone as well.

Interoperability

On the interoperability side, under "systems", interoperability is also a standards issue. The Open GIS Consortium (OGC) is making tremendous strides in interoperability of GI systems, *i.e.* GIS tools, because the OGC is totally industry-based and is even paid for by the industry. It does have two or three national mapping agencies down the line, and one or two university research groups are also involved, but it is totally user-driven, and most of the standards it produces are developed by professional standards people who are seconded to the committee. But the OGC is only looking at systems, they are not looking at data; and basically the average GIS vendor is saying that it is important that his system be able to accommodate all different types of data formats that exist. To a certain extent current systems all do that. There are still a few specific data conversion problems, but the software is getting more clever, and the hardware is always getting more powerful for less money. In most cases, you need not worry too much about what standard you are following, provided that you are following a standard, because the vendor will normally have something that is able to handle that standard.

The Web

At present the Web's main impact relates to its use for discovery, to use it to find where other people have data, and help you get in touch with them. Once you find out where certain data may exist, you can then speak to the owners of those data on the phone, or perhaps send them a fax or an e-mail, to find out more about the data. Whereas the Web of the future is likely to be more interactive, and this will have an impact. We will use the Web not to deliver data, which is what it can do today, but as a means to deliver information. At present, you can download data from the Web, you can download some maps, you can find some metadata, but the day will come when it delivers you some information which you can then use to build up knowledge. But the Web is never going to deliver you some knowledge.

Away from maps?

At the Cambridge Conference this year (sponsored by the UK Ordnance Survey), there were 240 members, representing 72 mapping agencies from around the world. It was interesting that the main conclusion to come out of this conference was that most mapping agencies are trying to re-engineer themselves. A few of them, for example those in Sweden and New-Zealand, no longer talk of themselves as mapping agencies: they are geographic information repositories; they are geographic information resource centres. They are actually producing new marketing literature, to get away from the fact that they once made maps. In the future, a map is just going to be a by-product of something they do. Now this is a radical change coming from the mapping side of GIS, and it is an underlying model that goes much deeper. The coastal zone community is a user community of maps. We also do create maps, mainly for visualisation purposes, to get information across to a local council or whoever, but this latter role is also now being taken on board by mapping agencies themselves, partly because they are going digital. The Ordnance Survey in Great Britain no longer has any maps; there is no map library any more; the "map" is completely contained within the computer. You want a map? They will create a map for you. They can create whole new products in two days, a product they did not have two days earlier. It is all on the database.

Managing 3D and 4D

Looking at GIS generally, and coastal zone managers as users, GIS is extremely important, both as a data visualisation tool and as a spatial analysis tool. But it goes back to a paradigm from the early sixties, when it was developed in Canada. It was two-dimensional, whereas in the coastal zone we have always needed three-dimensional. Also, GIS has never had a time base on it - it is not temporal - which is also something we need in the coastal zone. It was interesting to hear the heads of two or three major GIS vendor companies in the last year, talking about these issues at major conferences, suggest that "these are technological problems with GIS, but do not worry, we are moving ahead, and we shall solve the technical problems". In practice, we only saw experimental 3-D being built in to these packages in the past decade, and temporal GIS being built in during the past three or four years. They are still not ubiquitous and they need to be properly integrated with GIS, so we still have quite a way to go to get these tools to work properly. Until they do, no GIS packages at present can be used for process modelling by themselves. You have to create separate models to analyse coastal processes, and then use the GIS to show the results.

Impact of policy issues

There are a number of important GI policy-related issues in Europe that we need to be aware of, such as legal issues, access to data, the Freedom of Information Act, and so on. The importance of policy is often greatly underestimated. Certainly at the European level, especially within the 15 member states of the EU, if one good policy goes into place you can open up a whole new set of industries: for example, nobody five years ago thought we would see the national telephone monopolies of Europe broken but they are, and we can see all around us the results of this change in policy.

The European Commission is the executive body of Europe, and can issue directives that then have far-reaching down-stream impact. However, we are still lacking adequate European policies relating to GI. In five years of trying, five years of full-time lobbying effort, we have still not got a single person above the level of Director - and that is quite a low level within the Commission - to even accept that GI is important. Not GIS, not coastal zone GI, but even the basic concept of geographical information. So we are now embarking on another three-year effort to see if we can convince them that it is an important issue. We are going to be looking for some support from the user-community on this: for example asking you to lobby local associations, to get in touch with politicians, to find out who your Member of European Parliament is in Brussels and make representations to these people, because one well-placed policy change could have a huge impact on geographic information use, and possibly coastal information use, over the next decade.

François Cuq

Remote sensing

For a few years now, the pace of research in the area of remote sensing has slowed to a virtual halt, during which users have had time to become familiar with the existing technology. Thanks to various American, European and Japanese projects, we now have a clearer view of the world, seen through the sensors of a new generation of satellites. These are currently undertaking very high-resolution surveys of the world, using a number of spectral bands we had no access to in earlier years, especially with the arrival of multi-beam radar satellites. It is now time to launch a new programme of research into satellite imagery, with a view to extracting information that will allow us to better calibrate and parameterise the models we are trying to develop for integrated coastal zone management, as well as to monitor the state of coastal dynamics. We should remember that satellite or airborne imagery is an excellent means of obtaining information, especially for replacing or augmenting ground-acquired information in a spatially-integrated and objective way. While the utility of such approaches is clear, it also raises very interesting questions about how representative they are of the real world, in terms of scale and spatial pattern.

Decision support

Important work should be undertaken in coming years, on the theoretical basis of decision-making. If we want to work on, and with, tools that are real decision-support technologies for integrated coastal zone management, we clearly need to understand the mechanisms by which decisions are made, and the foundations of decision theory, far better than we do at present. Some work is already underway in these areas, but these endeavours keep coming up against hard reality. Decision-support systems at present work well when applied to hypothetical scenarios, but work less well when these scenarios are based on real-world situations. If we really want to see progress towards a new conceptual generation of GIS, it is essential to integrate decision-making concepts into these new systems. And, more generally, it is absolutely essential to incorporate into such systems the means of modelling the behaviour of human society in all of its many forms.

Lionel Loubersac

A dynamic environment

During 1999, three important meetings took place in Europe that were dedicated to GI and the coastal zone. These were Info-Coast in the Netherlands in February, the UK meeting on coastal cartography in June and now CoastGIS here in France. In the last two meetings, the coastal marine community was well represented, while in the Netherlands it was relatively weak in contrast to stronger coastal land community representation. Interestingly, one of the conclusions offered at Info-Coast was the suggestion that GIS implementation problems for marine coastal applications are similar to those arising for land applications. This surely is something difficult to agree with, particularly when seen from an offshore perspective. Here, we are dealing with a fluid environment, where everything moves: tides, currents, swell, pollution, fishes, even people. The challenges are to represent this environment in three or four dimensions and perhaps our coastal community compares itself too much with the land GIS community.

A world without property

When modelling land territory with GIS, you are working with geographic objects, areas or structures that generally have a recognized ownership: the field, the lighthouse, the road, the forest, all belong to "somebody" that is more-or-less recognized by other people. When you go into the water, the system of territorial appropriation is completely different. The coastal marine territory belongs to nobody (or to everybody). One possible explanation for the fragmentation of coastal information is that it results from the various views of this territory, with corresponding fragmentation of responsibilities. Before the availability of GIS, this fact was hidden. As we saw in the session of this meeting devoted to legal aspects, GIS generally, and coastal GIS specifically, can be a provocative tool. Perhaps we should use it as such, that is to deliberately provoke some brainstorming about the problem of dividing this offshore territory from various points of view. The very big difficulty we have, arising from this, is to understand and represent how this fragmentation of territorial claims relate to the coastal system in its wholeness.

Conclusions

The wide-ranging and thoughtful presentations made at CoastGIS'99, as well as the closing panel discussion reported on here, provide ample testimony to the vibrancy of the coastal GIS community as we head into the 21st Century. With the very open community represented at our meetings we have a real possibility, at the international level, to foster the sharing of perspectives among researchers, decision-makers, and technicians coming from the separate fields of GIS and integrated coastal zone management respectively.

The need for approaches to coastal management that go beyond the purely local or national, and the various factors that currently mitigate against achieving these more global perspectives, were much debated in Brest. Of particular interest here, were the several discussions about cultural nuances, the comparative terminology and semantics used in describing (and understanding) coastal spaces, and the ways that these shape people's perspectives and impact on our appreciation, use and regulation of the coast. In this regard, the very cosmopolitan nature of the CoastGIS series of meetings was seen as a major asset that deserved to be exploited and further developed. For example, one specific suggestion was that CoastGIS participants might collaborate *via* the Internet, to develop a series of linked Websites, in French, Spanish, English and other languages as required, explaining how the coastal environment is managed in different areas around the world, and offering good illustrations and case studies of such management issues and information problems (and, if appropriate, their solution) found in each region. As

well as building on and further consolidating inter-personal and inter-agency linkages made during the course of the meeting, it was felt that such an initiative might also lead to the creation of actual tools of practical benefit to anyone tasked with developing integrated, and international, coastal management policies.
It was also suggested that the conclusions of these symposia might be drafted in English and French. They could then be made available, as part of a broader "outreach" and lobbying initiative to decision-makers, policy analysts and all others who work on the co-ordination of (coastal) geographic information in our respective countries and at the European Commission. The fact that CoastGIS is jointly sponsored by two of the major international scientific bodies in relevant fields, namely the Commission on Coastal Systems of the International Geographical Union, and the Commission on Marine Cartography of the International Cartographic Association respectively, underscores and emphasizes the influence that such an initiative could potentially have in helping to shape future coastal management strategies.

Finally, in spite of the quality of the presentations shown at Coast-GIS'99, it was felt by some delegates that training programmes and other "technology transfer" problems had been somewhat overlooked when the contents and format of the meeting were decided on. Given that these are also very important issues, a suggestion was made that sessions devoted to these issues should be explicitly built in to the programme for the next CoastGIS meeting, due to take place in Halifax, Nova Scotia, in 2001.

Réalisation, mise en page : XLC (02 98 30 50 07)

Achevé d'imprimer sur les presses de l'établissement principal
du service hydrographique et océanographique de la Marine (Epshom : 02 98 22 15 84)

ISSN 0761-3962
ISBN 2-84433-036-3/Dépôt légal 2e trimestre 2000

CoastGIS'99: Geomatics and coastal environment

(Brest, 9-11 septembre 1999)

This publication contains a selection of papers presented at the CoastGIS'99 symposium, a gathering of over 150 scientists, planners and industrialists representing the international community for geographic information in the coastal environment.
The scientific, technical and socio-economic stakes for data, systems, communication and representation modes are discussed. In the light of regional experiences, we focus on institutional constraints : how can we draw up and then disseminate as widely as possible the high-quality information on the physical and human environments which can enable us to protect and make better use of our coastal areas ?

Keywords: GIS, geomatics, integrated management, coastal area, reference data, mapping.

CoastGIS'99 : Géomatique et environnement littoral

(Brest, 9-11 septembre 1999)

Cet ouvrage regroupe une sélection de communications présentées au colloque CoastGIS'99, où s'étaient réunis plus de 150 scientifiques, aménageurs et industriels représentant la communauté internationale de l'information géographique en milieu littoral.
Les enjeux scientifiques, techniques et socio-économiques des données, des systèmes, des modes de communication et de représentation y sont débattus. À la lumière d'expériences régionales, les contraintes institutionnelles y sont abordées : comment élaborer, puis assurer la circulation la plus large possible d'une information de qualité sur les milieux physique et humain, apte à nous aider à préserver et mieux utiliser notre espace littoral.

Mots-clés : SIG, géomatique, gestion intégrée, zone côtière, informations de référence, cartographie.

Ifremer

Ifremer actes de colloques

25

Éditions Ifremer
BP 70, 29280 Plouzané, France
tél. 02 98 22 40 13
fax 02 98 22 45 86
mél : editions@ifremer.fr

SHOM
3, avenue Octave Gréard
75007 Paris
tél. 01 44 38 41 16
fax 01 40 65 99 98
http://www.shom.fr

Diffusion

• ALT Brest
Service Logistique
3, rue Édouard Belin - BP 23
29801 Brest Cedex 9
tél. 02 98 02 42 34
fax 02 98 02 05 84
mél : alt.brest@alt.cci-brest.fr

• EPSHOM
13, rue du Chatellier, BP 426
29275 Brest Cedex
tél. 02 98 03 09 17
fax 02 98 47 11 42

ISSN 0761-3962
ISBN 2-84433-036-3

220 F - 33,54 €

9 782844 330369