BACKGROUND BRIEF

Prepared by the ACZISC Secretariat for a

LARGE MARINE ECOZONE BOUNDARY WORKSHOP

12 September 2003
Bedford Institute of Oceanography
Dartmouth, Nova Scotia

WORKSHOP OBJECTIVES

To review the criteria and rationale taken by DFO, EC, NRCan and Parks Canada, and other governments and agencies, to define and delineate large marine ecoregions, to assess differences and commonalities and to define, if possible, common spatial planning frameworks

WORKSHOP RATIONALE

Managing Canadian waters is a multi-jurisdictional responsibility. The identification of common ecozone boundaries by the responsible jurisdictions would appear to be logical and have several practical advantages, including: spatial planning/zoning; environmental assessments; planning for marine protected areas; and research priorities.

Therefore, can the relevant federal departments come to a consensus on a classification system to define and delineate the large marine ecoregions in Atlantic Canada?

BACKGROUND BRIEF

The Background Brief provides an overview of selected efforts, primarily Canadian, to develop a methodology for the delineation of ecoregions. This brief is not original research but merely a summary of other peoples' work.

With the permission of the authors, extensive use is made of documents that have not been published to date.

The ACZISC Secretariat would like to acknowledge the contributions of the Workshop Steering Committee and in particular those who have contributed to this briefing document: Scott Coffen-Smout and colleagues, OCMD/DFO; Gordon Fader and Vladimir Kostylev, GSCA/NRCan; Larry Hildebrand, EC; and Francine Mercier, PC.

It is hoped that the contents will provide sufficient information to stimulate and focus the workshop deliberations.

TABLE OF CONTENTS

BACKGROUND BRIEF

LARGE MARINE ECOZONE BOUNDARY WORKSHOP

THE MARINE ANTECEDENT: ECOLOGICAL LAND CLASSIFICATION

Ecological land classification is "a process of delineation and classifying ecologically distinct areas of the earth's surface. Each area can be viewed as a discrete system which has resulted from the mesh and interplay of the geology, land form, soil, vegetation, climatic, wildlife, water and human factors which may be present" (Wiken, 1986). Ecosystem may be defined as a dynamic complex of organisms, including humans, and their physical environment, which interact as a functional unit in nature. 'Eco' is derived from the Greek work 'oiko' meaning habitation (CEC, 1997).

Methodology (CEC, 1997): Diagnostic criteria for individual mapped areas are based on 'enduring' components of the ecosystem contained therein, *e.g.*, soil, landform or major vegetation type. Key points include:

- Ecological classification incorporates all major components of ecosystems.
- It is holistic - the whole is greater than the sum of the parts.
- The number and relative importance of the delineation factors varies from area to area.
- Ecological classification is based on hierarchy; ecosystems are nested within ecosystems.
- Soil classification integrates knowledge; it is not an overlay process.
- Characteristics of one ecosystem blend with those of another.
- Map lines depicting ecological classification boundaries coincide with the lines of transition.

Ecological Framework (CEC, 1997): Four divisions were identified in Canada, with their numbers indicated in parenthesis:

- Ecozone (15) is the top of the hierarchy and defines the ecological mosaic of Canada on a sub-continental scale. See page 9 in CEC (1997).
- Ecoprovince (53) is a subdivision of an ecozone characterized by major assemblages of structural or surface forms.
- Ecoregion (194) is a subdivision of an ecoprovince characterized by distinctive regional ecological factors.
- Ecodistrict (1021) is a subdivision of an ecoregion.

Chronology: Marshall and Schutt (1999) summarized the development of classification schemes particularly as they relate to the terrestrial environment:

- Since the 1960's numerous governments, NGOs, universities and industry have worked to develop a common hierarchical ecosystem framework and terminology.

- In the 1970's the process gained momentum following the creation of the Canadian Committee on Ecological Land Classification.
- Parks Canada's National Parks System Plan of 39 natural regions was developed in 1970 and with few exceptions is consistent with the current terrestrial ecozone classification (pers. com. F. Mercier).
- In 1991 a number of federal and provincial agencies under the auspices of the Ecological Stratification Working Group revised previous work to establish a common ecological framework for Canada, focusing on ecozones, ecoregions and ecodistricts.
- In 1996 the resulting national report "A National Ecological Framework for Canada" was released by the Ecological Stratification Working Group.
- In 1996 the "Ecoregions of British Columbia" was published and that same year the Canadian Council on Ecological Areas (CCEA) released "A Perspective on Canada's Ecosystems". Others followed:
    - In 1997 "Ecological Regions of North America: Towards a Common Perspective" by the Commission for Environmental Cooperation (CEC)
    - In 1998 "Ecoregions of Saskatchewan" and "Terrestrial Ecozones, Ecoregions and Ecodistricts of Manitoba: an Ecological Stratification of Manitoba's Natural Landscape"
    - In 1999 "Ecoregions and Ecodistricts of Nova Scotia".

FROM LAND TO SEA

The delineation of the boundaries in the ocean presents additional challenges to those faced on land (Courtney and Wiggin, 2003):

- the lack of consistent spatial data
- the lack of information on the resources
- the lack of data necessary to understand the physical dimension, the Seascape, of areas under consideration for spatially specific management
- the multidimensional nature of the marine environment
- the importance of an objective scientific system to set boundaries
- zones are meant to be static but some of the living resources, the subject of the zone, may be highly mobile
- a change in environmental conditions may cause target species to migrate out of a protected zone, hence a monitoring system will be needed.
- the limited understanding of complex biological relationships within an ecosystem makes it difficult to anticipate the impact of restrictions in a particular area
- the difficulty of establishing the right zone boundary to achieve the intended purpose
- the difficulty of communicating the boundaries to the users
- the difficulty of monitoring and enforcement.

NECESSARY ATTRIBUTES OF A MARINE CLASSIFICATION SYSTEM

Hedgpeth (1957) in chapter 2 of the "Treatise on Marine Ecology and Paleoecology" reviewed the historic (1850-1950) efforts to classify the marine environment. He points out the plethora of contradictions, overlaps, errors and general confusion associated with many of these studies. A case in point are the numerous interpretations of the 'littoral zone'

According to Watson (1997) a marine classification system must be scientifically rigorous, and hierarchical, and also:

- the system must clearly delineate, using recognizable criteria, repeating community or habitat types that occur within an ecosystem
- it must have predictive power, describing the relationship between physical environments and biotic communities
- classification systems must correspond to species distribution so that if characteristic species are protected, biological diversity will be maintained
- classification systems should be hierarchical so that description occurs on different spatial scales
- the system should have a global perspective in which the higher levels of classification are defined by global processes
- in a physical classification the criteria used must be determinants of the biological community structure.

RATIONALE FOR HABITAT CLASSIFICATIONS AND MAPPING

Day and Roff (2000) identified a suite of applications for habitat classifications and mapping:

- *Habitat-community type association*: The relationship between habitat type and community type can only be verified by direct sampling. Habitat mapping provides guidance for sampling regimes.
- *Habitat suitability assessment:* Mapping of environmental variables permits assessment of habitat suitability (spawning, feeding, etc.) for commercial spp and also to assess the potential conflicts between conservation and resource utilization goals.
- *Biodiversity distribution:* Analyses of biodiversity in relation to geophysical factors are vital to conservation efforts.
- *Invasive species:* Because of a species fidelity to the basic geophysical characteristic of its original habitat, it should be possible to predict the range of an invading species in its new location.
- *Candidate MPAs:* Habitat mapping is an indispensable preliminary stage in evaluating potential MPA sites.
- *Focal species:* Public support for conservation identifies with charismatic 'focal' or 'flagship' species (*e.g.*, large marine mammals). Their distribution in relation to habitat must be mapped to evaluate conservation strategies.
- *Monitoring and management:* Maps of habitat types aid the assessment and prediction of likely impacts of human effects on benthic communities and, for

monitoring purposes, several criteria may be used to assess 'health' such as the number of spp and their diversity.
- *Reference areas (those unaffected by human activities):* These may not be present in some jurisdictions but with this classification scheme a corresponding area maybe found elsewhere.
- *Ecosystem processes:* These provide a framework to judge interactions of habitat and community structure and time dependent ecosystem-level processes such as re-colonization.
- *Global warming:* This enables an evaluation of climate change scenarios and for prediction of impacts in the marine environment. Note: If this classification scheme was based on surveys of biological organisms alone, their distribution would change continually under global warming so necessitating constant sampling. But as geophysical factors are the key determinants, habitat boundaries can be redrawn according to modeled scenarios and the impacts predicted.

MARINE CLASSIFICATION SYSTEMS

Day and Roff (1998) reviewed the various classifications undertaken for Canada's oceans, provided a brief synopsis of each and included perspectives on the advantages and disadvantages of each classification and a comparison of the marine ecological attributes employed in the classification criteria:

- Parks Canada (Harper *et al*., 1983) which was updated with minor boundary revisions and forms the basis of the National Marine Conservation Areas System Plan (Mercier and Mondor, 1995)
- IUCN global classification of coastal and marine environments (Hayden *et al.*, 1984)
- Global Representative System of MPAs (*e.g.*, Kelleher *et al.*, 1995)
- CCLEC Framework for Ecosystem Classification (see Geomatics International Inc., 1996 and Wickware and Rubec, 1989)
- Environment Canada (Harper *et al.*, 1993)
- BC Environment (Demarchi, 1996)
- Development of a biophysical classification of offshore regions for the Nova Scotia continental shelf (Davis *et al.*, 1994).

Day and Roff (1998) also reviewed and critiqued the major international approaches to classifying marine areas:

- Australia: the Interim Marine and Coastal Regionalisation for Australia (IMCRA Technical Group, 1997)
- Britain: the British Marine Nature Conservancy Review program has developed a hierarchical classification method (Hiscock and Mitchell, 1980; Hiscock and Connor, 1991; Connor *et al.*, 1995; Hiscock, 1995)
- Europe: a study by AIDEnvironment (Nijkamp and Peet, 1994) recommended a three step strategy to develop a well designated network of MPAs in Europe following the identification of marine biogeographic regions and large marine ecosystems

The European Union Nature Information System (EUNIS) has been under development for a number of years with the goal of establishing a habitat classification system for all terrestrial and aquatic lands. As an ICES country, Canada has committed to considering the application of the EUNIS system. The system and background documentation may be viewed at http://mrw.wallonie.be/dgrne/sibw/EUNIS/eunis.fulllistA.html

- USA: the most widely used system is hierarchical, consisting of systems, subsystems, classes and subclasses together with a series of modifiers, which assess water regime, chemistry, and soil (Cowardin *et al.*, 1979; Cowardin and Golet, 1995; Watson, 1997). Brown (1993) compared eight classification systems previously used in the US.

THE PARKS CANADA APPROACH

Within the context of Canada's National Marine Conservation Areas (NMCA) System Plan, articulated by Parks Canada (Mercier and Mondor, 1995), the intent was to subdivide the marine environment into distinct geographic units (marine regions) based on oceanographic and biological characteristics and set aside a representative sample of each region within the NMCA system.

The NMCA System Plan of 29 marine regions is based on a report prepared for Parks Canada by Harper *et al.* (1983). The marine regions were defined by systematically combining physical and biological theme maps to provide a greater level of detail than the marine framework being used at the time (Paish, 1970). The approach relied heavily on a consensus of marine specialists representing a wide range of marine disciplines.

The rationale for the delimitation of the marine regions, based on Harper *et al.*, 1983, was as follows:

- to make the best use of existing information
- to consider physical features (oceanography, coastal environment and physiography) and biological features (marine birds, marine mammals, fish and invertebrates)
- to minimize 'contested areas'
- to keep the number of regions down to a reasonable number
- to give equal weight to physical and biological features.

Methodology:

- use specialists to develop theme maps, *e.g.*, marine bird distribution, physiographic regions
- develop biological and physical base maps by combining the relevant theme maps
- develop Marine Region Maps by combining the physical and biological base maps
- submit the Marine Regions Maps for evaluation and subsequent revision at a workshop of marine experts.

Delineation guidelines:

- when two or more theme boundaries coincide, adopt it
- when two theme boundaries are near to each other and generally parallel, adopt a boundary equidistant between them
- when a single theme boundary is important, adopt it
- when three boundaries are near to each other and generally parallel, treat the nearest two lines according to the first guideline and the other according to the third guideline.

Limitations:

- subjective judgments
- boundaries are drawn as lines but are really zones with an undefined spatial dimension
- regions are schematically drawn to extend to political boundaries or the 200 mile limit (in recognition of the fact that NMCAs require a land base)
- the theme maps were often based on general distribution maps with few data points.

Results: Since 1983, boundaries have been adjusted to take account of new information, but the total number of regions has remained at 29, of which ten are on the Atlantic coast: Hudson Strait, Labrador Shelf, Newfoundland Shelf, North Gulf Shelf, St. Lawrence Estuary, Magdalen Shallows, Laurentian Channel, Grand Banks, Scotian Shelf, Bay of Fundy. Refer to page 59, Mercier and Mondor (1995).

THE DFO APPROACH: AN OCEANS ACT OUTCOME

With the passage of the Oceans Act in 1997 and the subsequent development of Canada's Ocean Strategy and its associated Integrated Management Framework (DF0, 2002), a new focus developed on 'management by areas', which predicated that:

- integrated management objectives and planning practices must reflect that ecosystems nest within other ecosystems, from Large Ocean Management Areas (LOMAs), to Ocean Management Areas (OMAs), and to smaller Coastal Management Areas (CMAs)
- management for sustainable development recognizes that most problems and opportunities in the oceans start on land, thus the need to integrate land use practices of watersheds
- for practical purposes, the boundaries of the LOMA/CMAs will be drawn using a mix of ecological consideration and administrative boundaries.

Each of Canada's LOMAs covers a large portion of one of its three oceans or coastal zones, typically extending from the coast to the limit of Canada's jurisdiction, *e.g.*, the Eastern Scotian Shelf Integrated Management (ESSIM) area.

Major considerations include how the CMAs relate to the LOMA in which nested, to the adjacent coastal land mass and waters, and to the impact of land-based activities - hence

the importance of the National Program of Action for Protection of the Marine Environment from Land-Based Activities.

Eastern Scotia Shelf Integrated Management (ESSIM) Initiative
"Announced as Canada's first integrated ocean management pilot with an offshore focus under the 1997 Oceans Act, the ESSIM Initiative has since evolved to include coastal areas through the establishment of the Large Ocean Management Area (LOMA) concept in DFO's Policy and Operational Framework for Integrated Management of Estuarine, Coastal and Marine Environments in Canada, released in July 2002" (DFO, 2003). This policy provides the national structure and guidance for the development of regional ocean management and planning processes.

ESSIM Area of Application: The management area is defined according to major oceanographic and bathymetric features and is located within the jurisdiction of the Maritimes Region of DFO and corresponds with the NAFO Division 4V/W. The outer boundary extends beyond the 200 nm EEZ to include Canada's extended continental shelf claims under the 1992 UN LOS Convention. The inner boundary includes coastal and estuarine waters as interpreted under the Oceans Act.

ESSIM Characterization/Delineation Process: The LOMA approach to ecosystem characterization is based on water movements and the physical and chemical characteristics of the water column that collectively determine the abundance and distribution of marine organisms.

Each OMA is described in terms of vertical ecozones which, combined with the assemblage of contained living organisms, define the ecotypes. A benthic characterization framework is currently being developed for the Scotian Shelf to further support ecosystem-based management (DFO, 2002).

However, even with an increasing appreciation of the biophysical and ecological factors involved, the difficulty of delineating a clear boundary in the marine environment is acknowledged. Although the various management areas have been identified on an ecosystem basis, the LOMA and contained OMAs have been modified by jurisdictional and administrative considerations.

THE GSC/NRCAN APPROACH: CLASSIFICATION AND MAPPING

Fader (2002) reviewed published maps, limitations, future uses and recent advances in seabed mapping in relation to the surficial sediments of the Scotian Shelf. He assessed the maps in terms of three requirements:

- the distribution of materials and their associated properties
- the morphology of the seabed (commonly defined as bathymetry)
- an understanding of seabed dynamics (erosion, deposition, sediment transport, stability).

Fader concluded that existing surficial maps of the Scotian Shelf are very limited in their potential for seabed management. To address these shortcomings, multibeam bathymetric mapping and its associated thematic products of morphology, backscatter (proxy for sediment type), slope, interpreted geology and habitat maps are required, *e.g.*, the SeaMap proposal.

Over the past decade, the Geological Survey of Canada has become increasingly involved in the application of marine geoscience to habitat characterization. This is a result of significant advances of seabed mapping technologies and an understanding of seabed processes. Seabed mapping at NRCan is carried out by geologists working closely with marine biologists, with the recognition of the importance of geological seabed attributes with regard to the structure and function of benthic communities (Fader *et al*., 2000).

Classification of the benthic environment is required for the educated management of natural resources. This demands knowledge of the distribution of marine ecosystems, their function, biological diversity and their geographically accurate representation on maps. Classification and mapping, however, have different goals: ecological classifications are aimed at identifying (often arbitrarily) differences between systems and developing a common nomenclature. Mapping, in contrast, is assumed to correctly represent the environment and has inherently practical purposes (Kostylev, 2002).

Top-down Versus Bottom-up Approaches to Classification (Kostylev, 2002):
Top-down: If environmental factors are classified and mapped with the belief that the zonations will conform to habitat delineation, then there must be an assumption that there is a relationship between the physical factors and the biological components.

Bottom-up: If habitat is mapped based on species distribution, then it must be assumed that species assemblages adequately represent environmental factors that are ultimately responsible for shaping the communities.

Because of the inherent errors in both approaches and the fact that boundaries on maps are either arbitrary or approximate, Kostylev (2002) recommends a combination of both techniques and cross validation.

Benthic Habitat Mapping (Kostylev *et al*., 2001 and Kostylev *et al*., in prep.):
For the purpose of mapping the term 'habitat' is applied to a spatially defined area where the physical, chemical and biological environment is distinctly different from the surrounding environment.

Rationale: Mapping sea floor habitat is fundamental to scientific fisheries management, for monitoring environmental change and for assessing the impact of anthropogenic disturbance on benthic organisms.

Biological Objectives: To discriminate distinct assemblages of benthic megafauna (organisms larger than 1 cm in linear dimension); to correlate the relationship between seafloor surficial sediment, oceanographic variables and biota; and to map the defined benthic habitats.

Biophysical 'Assumptions': Assemblages of species, rather than individual species, are considered because groups of organisms best reflect the distribution of physical factors. It is assumed that the organisms distribute themselves along environmental gradients and that clusters of organisms define distinct sets of environmental characteristics.

Methodology: This interdisciplinary habitat mapping study is based on the analysis of megabenthos identified by seafloor photography integrated with an interpretation of multi-beam bathymetric data and associated geoscientific information. Discrimination of benthic assemblages and discrimination of significant physical factors is achieved by cluster analysis, ordination and similarity analysis.

Results:

- With the acknowledgement that there was a general lack of information re benthic infauna and associated detailed stratigraphy, six habitat types and corresponding associations of benthic animals were mapped on the Browns Bank (Figure 12, page 133 in Kostylev *et al.*, 2001). Substrate type and water depth served as proxies for a number of co-varying physical factors.
- In the Sable Island Gully area seven assemblages were defined, and their associations with geological and oceanographic features described (Kostylev, 2002). It was shown that oceanographic factors in addition to geomorphology play a role in faunal differentiation in the area.

In a subsequent study on Georges Bank, Kostylev *et al.* (in prep.) implemented an approach to habitat mapping based on the selective forces acting upon benthic fauna, *i.e*. a classification based on defining habitats in terms of two main characteristics, 'adversity' or physical stress and 'stability' or temporal persistence of habitat structure. These two factors capture both geological and oceanographic information in defining habitat types. See Figure 9 and explanation on page 15 in Kostylev *et al.* (in prep.). According to Kostylev *et al*. (in prep.), the advantage of this "habitat template" approach is that it appears to be theoretically valid and avoids the difficulty of simultaneously interpreting large numbers of environmental variables (*e.g*., water temperature, salinity, bathymetry, geology, etc.) for decision-making. The approach provides managers with a rough guideline as to which areas of the seafloor are naturally disturbed or benign, which can lead to better management decisions.

THE WORLD WILDLIFE FUND CANADA APPROACH

In parallel with the GSC/NRCan studies, the World Wildlife Fund Canada sponsored a report entitled “Planning for Representative Marine Protected Areas: A Framework for Canada’s Oceans” (Day and Roff, 2000):

Rationale: “The systematic identification of marine habitat types and the delineation of their boundaries in a consistent classification is a basis for selecting examples of Canada’s marine areas that can contribute to a representative network of MPAs” (Day and Roff, 2000). The hierarchical framework is based on ecological principles and on the enduring and recurrent geophysical and oceanographic features of the marine environment.

Characteristics: It differs from previously developed classifications as follows:

- Physical attributes alone are used to predict the expected species assemblages within specific geographic units or 'seascapes'. Therefore boundaries between habitat types can be defined even when biological data is lacking.
- Two major marine environments are classified, the pelagic and the benthic realms, which have different communities and ecological processes.
- Because of reliance on geophysical features, this classification identifies natural habitats even in areas heavily affected by human usage.

Benefits:

- a defensible marine classification based on a minimal set of physiographic and oceanographic features
- provides a mechanism to evaluate candidate MPAs from an ecological perspective and subsequently to monitor them
- a framework to plan and manage Canada's marine environment
- similar frameworks for the hierarchical classification of all aquatic habitats could be developed.

Application (Scotian Shelf Case Study): The National Marine Classification scheme with its eight levels of discrimination is indicated in Day and Roff (2000) - Table A1, page 108.

- Nine natural regions are derived for the Scotian Shelf by the combination of temperature and vertical segregation in Day and Roff (2000) - Map 5, page 119.
- Nine natural regions and 62 seascapes, the lowest unit of classification, are shown in Day and Roff (2000) - Map 10, page 129. The seascapes are derived by the combination of data for temperature, vertical segregation, benthic temperature, stratification (pelagic), exposure (benthic) and sediment (benthic).

The Scotian Shelf Case Study was recently augmented by the application of the methodology to the entire Canadian coastline out to the 200 nm limit (Roff *et al.*, 2003). A classification of habitat for such an extended geographic area predicates a geophysical classification as surrogate for marine community types.

Considerations:

- Marine communities are differentiated either taxonomically or according to habitat.
- Schemes to classify habitats at a local, regional and higher levels may identify different sets of factors as determinants and use them in different sequences in a hierarchical classification scheme.
- The availability of geophysical data and its potential acquisition by remote or in situ sensing must be considered.
- A combination of factors may be used as surrogates of others.
- The factors chosen for a classification hierarchy within a region will depend upon the natural range of variation of each, *i.e.* little variation would exclude the factor.
- The sequence in which factors enter a hierarchy should depend on which has the greatest ability to discriminate among habitat types.

A comparison of marine ecological attributes employed as classification criteria in existing marine classification systems can be found in Day and Roff (1998).

AN INTERDISCIPLINARY AND INTER-SECTORAL APPROACH TO BENTHIC HABITAT CLASSIFICATION

At a Benthic Habitat Classification Workshop Meeting of the Maritimes Regional Advisory Process hosted by DFO in June 2001 (DFO, 2002), Bruce Hatcher presented a detailed literature review in support of "a scientifically defensible, legislatively robust and spatial-explicit benthic classification scheme for the massive Scotian Shelf ecosystem" (Hatcher, 2002). The interdisciplinary and inter-sectoral Workshop participants arrived at a consensus on nine framework recommendations:

- development of a management oriented model for benthic classification
- set classification scales by capacity for compliance and enforcement
- classify hierarchically and zone adaptively from the upper levels
- use the benthic assemblages as the Minimum Ecological Unit (MEU)
- incorporate oceanographic and trophodynamic processes
- incorporate the role of history in classification of benthic habitats
- operationalize classification by mapping enduring habitat units
- map benthic habitats first on the basis of shelf-scale synopses
- relate habitat complexity to biodiversity.

Currently under consideration is a proposed hierarchical classification scheme where all levels (four) are nested in higher levels and no attribute at one level exists at another level:

Level 1: Oceanographic Domains (six recognized)
- North-eastern Scotian Shelf
- South-eastern Scotian Shelf
- Central Scotian Shelf
- Western Scotian Shelf
- Scotian Shelf Edge
- Gulf of Maine (including Georges Bank and Bay of Fundy)
    - Classifying attributes (five):
        - Critical depth
        - Thermal regime
        - Current regime
        - Productivity regime
        - Disturbance regime

Level 2-3: Seabed Domains within Oceanographic Domains
- Physiographic domains (four)
- Morphological domains (eight) within each physiographic domain
- Scales of seabed texture (four) within each morphological domain

Level 4: Biological Communities: Five categories of metrics/variates were recognized.
- Within habitat species diversity

- Frequency of occurrence, biomass, abundance of individual species
- Degree of association between species and physical habitats
- Dominant megafaunal species
- List of associated species for each habitat type.

OTHER DEVELOPMENTS IN BOUNDARY DELINEATION

The following projects will contribute to the understanding of the boundary delineation process:

- 'New' mapping and analytical tools are being used in support of boundary delineation, *e.g.*, Multibeam sonar; Web-based GIS (Sutherland, 2002); Spatial Multi-Criteria Analysis (Villa, 2002) and Ecosystem-Based Predictive Modeling (Salomon, 2002).
- A Geomatics for Informed Decisions (GEOIDE) Research Network project entitled "Good Governance of Canada's Oceans: the Use and Value of Marine Boundary Information" (Sutherland, 2002) is intended to better determine the information requirements for ocean governance, develop visualization tools, model boundary uncertainty and use ocean mapping technologies to illustrate boundary delineation issues.
- The Gulf of Maine Mapping Initiative (GOMMI) will map the seafloor of the Gulf of Maine utilizing a range of visualization tools (*e.g.*, multi-beam sonar and laser scanning technologies). The results are intended to support efforts to appropriately site a wide variety of specific ocean uses, assist boundary delineation for MPAs, etc.
- In March 2001 the Offshore Issues Committee of the Association of Canada Lands Surveyors (ACLS) organized a workshop in Halifax to address a common concern of how property rights and structures are surveyed, charted and recorded in Canada's offshore (Nichols *et al.*, 2001). The timing of the Workshop was considered opportune in view of the following:
    - the ACLS under new legislation has an opportunity to take on greater responsibility for leadership in marine boundary and related issues
    - there is a growing awareness of the need for ocean management and co-management strategies
    - there is a common understanding and goal among stakeholders of the need for improved information management and the fact that we may have the information technologies but still lack the institutional structures in the offshore
    - there is a critical need to develop Canada's international leadership role in the offshore, especially with the economic opportunities abroad and the fact that the UN Convention of the Law of the Sea is now in force

  The March 2001 ACLS Workshop specifically addressed and achieved a measure of consensus on four major topics: survey issues; data sharing/public registry; jurisdiction and property rights infrastructure; and marine cadastre and geospatial data infrastructure (Nichols *et al.*, 2001). Other follow-up workshops are planned.

BIBLIOGRAPHY

Brown, B., 1993. *A classification system of marine and estuarine habitats in Maine: An ecosystem approach to habitats Part 1: Benthic habitats*. Marine Natural Areas Program, 51 p+

Commission for Environmental Cooperation, 1997. *Ecological regions of North America: toward a common perspective*, 71 p.

Connor, D.W., K. Hiscock, R.L. Foster-Smith and R. Covey, 1995. "A classification system for benthic marine biotopes". In Eleftheriou, A., Ansell A. D. and Smith C. J. (eds) *Biology and Ecology of Shallow Coastal Waters:* 155-166. European Marine Biology Symposium, Hersonissos, Crete (Greece), 1993. Fredensborg - Denmark Olsen and Olsen.

Courtney, F. and J. Wiggin, 2003. *Ocean zoning for the Gulf of Maine: A background paper*. Prepared for the Gulf of Maine Council for the Marine Environment, 32 p.

Cowardin, L.M. and F.C. Golet, 1995. "U.S. Fish and Wildlife Service 1979 wetland classification: A review". In *Vegetation, 118: 134-152*

Cowardin, L.M., V. Carter, F.C. Golet and E.T. LaRoe, 1979. *Classification of wetlands and deepwater habitats of the United States*. U.S. Department of the Interior Report FWS/OBS-79/31.

Davis, D S, P.L. Stewart, R.H. Loucks and S. Browne, 1994. "Development of a biophysical classification of offshore regions for the Nova Scotia continental shelf". In *Proceedings of the Coastal Zone Canada 1994 Conference, Halifax, NS: 2149–2157*.

Day, J.C. and J.C. Roff, 2000. *Planning for representative Marine Protected Areas: A framework for Canada's Oceans*. Report prepared for World Wildlife Fund Canada, 147 p.

Day, J.C. and J.C. Roff, 1998. *Planning for representative Marine Protected Areas: A framework for Canada's Oceans and the Great Lakes*. Report prepared for World Wildlife Fund Canada.

Demarchi, D.A., 1996. *An introduction to the ecoregions of British Columbia*. Wildlife Branch, Ministry of Environment, Lands and Parks, Victoria, B.C., 47 p.

DFO, 2003. *The Eastern Scotian Shelf Integrated Management (ESSIM) Initiative: A strategic planning framework for the Eastern Scotian Shelf Ocean Management Plan*. A discussion paper prepared for the ESSIM Forum, 37 p.

DFO, 2002. *Canada's Oceans Strategy: Policy and operational framework for integrated management of estuarine, coastal and marine environments in Canada,* 36 p.

DFO, 2002. *Proceedings of a benthic habitat classification workshop meeting of the Maritimes Regional Advisory Process*. Canadian Science Advisory Secretariat, Proceedings Series 2002/023.

Fader, G.B.J., 2002. "The surficial sediments of the Scotian Shelf: A review of published maps, limitations, future uses and recent advances in seabed mapping". In *Proceedings of a benthic habitat classification workshop meeting of the Maritimes Regional Advisory Process*. Canadian Science Advisory Secretariat, Proceedings Series 2002/023.

Fader, G.B.J., R.A. Pickrill, B.J. Todd, R.C. Courtney and D.R. Parott, 2000. "The emerging role of marine geology in benthic ecology". In *Geol. Survey Can. Tech. Pap. 00-16: 1-9.*

Geomatics International Inc., 1996. *National Framework and Methodology for the Determination of Marine Representation and Ecological Integrity*. Report prepared for World Wildlife Fund, 45 p.

Harper, J.R. *et al.*, 1993. *A classification of the marine regions of Canada*. Final report to Environment Canada by Coastal and Oceans Resources Inc., Sidney, BC, 77 p.

Hayden, J.R. *et al.*, 1984. "Coastal sensitivity analysis of the northern Chukchi Sea coast of Alaska". In *Proceedings of the 7th Arctic Marine Oil Spill Program (AMOP) Technical Seminar (Edmonton, AB), May 1984: 278-294.*

Harper, J.R., J. Christian, W.E. Cross, R. Frith, G. Searing and D. Thompson, 1983. *Marine regions of Canada: Framework for Canada's system of national marine parks*. Report prepared for Parks Canada by Woodward-Clyde Consultants, Victoria, BC.

Hatcher, B., 2002. "Literature review". In *Proceedings of a benthic habitat classification workshop meeting of the Maritimes Regional Advisory Process*. Canadian Science Advisory Secretariat, Proceedings Series 2002/023.

Hayden, B.P., R. Dolan and G.C. Ray, 1982. "A system of biophysical provinces in coastal and marine habitats for conservation purposes". In *Proceedings of the World National Parks Congress, Bali, Indonesia*.

Hedgpeth, J.W. (ed), 1957. *Treatise on marine ecology and paleoecology.* The Geological Society of America, Memoir 67.

Hiscock, K. (ed), 1995. "Classification of benthic marine biotopes of the north-east Atlantic". In *Proceedings of BioMar - Life Workshop, Cambridge, November 16-18 Nov. 1994*. Peterborough Joint Nature Conservation Committee, 105 p.

Hiscock, K. and D.W. Connor, 1991. *Benthic marine habitats and communities of Britain: The development of an MNCR classification*. Peterborough, Joint Nature Conservation Committee, Report No. 6., 92p.

Hiscock, K and R. Mitchell, 1980. "The description and classification of sublittoral epibenthic ecosystems". In *J.H. Price, D.E.G. Irvine, W.F. Farnham (eds.) The Shore Environment, Vol. 2. Ecosystems: 323-370.*

IMCRA Technical Group, 1997, Thackway R. and I.D. Cresswell (eds.) *Interim marine and coastal regionalization for Australia: an ecosystem-based classification for marine and coastal environments* (Version 3.2), Environment Australia, Commonwealth Department of Environment, Canberra.

Kelleher, G., C. Bleakley and S. Wells (eds), 1995. *A Global Representative System of Marine Protected Areas*. Great Barrier Reef Marine Park Authority, The World Bank, The World Conservation Union (IUCN).

Kostylev, V.E., B.J. Todd, O. Logva and P.C. Valentine, in prep. *Characterization of benthic habitats on Georges Bank*.

Kostylev, V.E., 2002. "Challenges in habitat classification and mapping". In *Proceedings of a benthic habitat classification workshop meeting of the Maritimes Regional Advisory Process*. Canadian Science Advisory Secretariat, Proceedings Series 2002/023.

Kostylev, V.E., 2002. "Benthic assemblages and habitats of the Sable Island Gully". In *Gordon, D.C. and D.G. Fenton (eds.). Advances in Understanding The Gully Ecosystem: A Summary of Research Projects Conducted at the Bedford Institute of Oceanography (1999-2001). Can. Tech. Rep. Fish. Aquat. Sci. 2377: 22-35.*

Kostylev, V.E., B.J. Todd, G.B.J. Fader, R.C. Courtney, G.D.M. Cameron and R.A. Pickrill, 2001. In *Benthic habitat mapping on the Scotian Shelf based on multibeam bathymetry, surficial geology and seafloor photographs. Marine Ecology Progress Series 219: 121-137.*

Marshall, I.B. and P.H. Schutt, 1999. *A national ecological framework for Canada: overview*. Agriculture and Agri-Food Canada.

Mercier, F. and C. Mondor, 1995. *Sea to sea to sea: Canada's National Marine Conservations Areas system plan*. Canadian Heritage, Parks Canada, 106 p.

Nichols, S., M. Sutherland, S. Ng'ang'a and D. Monahan, 2001. *Proceedings and report on the Association of Canada Lands Surveyors (ACLS) offshore issues consultation workshop, March 2001, Halifax, NS*.

Nijkamp, H. and G. Peet, 1994. *Marine Protected Areas in Europe*. Report of a Study within the BioMAr Project commissioned by the LIFE programme of the Commission of European Communities, AIDEnvironment, Amsterdam.

Paish, H., 1970. *The Canadian marine environment as a national park theme: a reconnaissance study*. Report prepared for Indian and Northern Development, National Historic Park Branch Ottawa, 43 p.

Roff, J.C., M.E. Taylor and J. Laughren, 2003. "Geophysical approaches to the classification, delineation and monitoring of marine habitats and their communities". In *Aquatic Conserv: Mar. Freshw. Ecosyst. 13: 77-90*.

Salomon, A.K., N.P. Waller, C. McIlhagga, R.L. Unug and C. Walters, 2002. "Modeling the trophic effects of marine protected area zoning policies: A case study". In *Aquatic Ecology, Vol. 36, No. 1: 85-95.*

Sutherland, M., 2002. "Marine boundary delimitation for ocean governance". In *Proceedings of the FIG International Congress, Washington D.C., April 2002*.

Watson, J., 1997. *A review of ecosystem classification: delineating the Strait of Georgia.* Report to DFO, Science Branch, Marine Environment and Habitat Science Division, Pacific Region, North Vancouver, BC, 81 p.

Wickware, G.M. and C.D.A. Rubec, 1989. *Ecoregions of Ontario*. Ecological Land Classification Series No. 26. Environment Canada, Ottawa, ON.

Wiken, E.B., 1986. *Terrestrial ecozones of Canada*. Ecological Land Classification Series No. 19, Environment Canada, Hull, Québec, 26 p.