The Future of Aquatic Science in Canada

(Oceans emphasis)

The Blue Paper

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"Predicting the future is easy. It's trying to figure out what's going on now that's hard". (Fritz Dressler)

I - INTRODUCTION

Many government agencies and stakeholder organisations contribute to provision of a safe, healthy environment and conservation and management of aquatic resources in Canada. As the pace of environmental, social and economic change accelerates, these organisations must re-evaluate and adjust their activities to address emerging realities. It is important that these adjustments be made within the context of an informed long-range view of the future, and that change occur proactively. Because it provides the foundation of conservation, management and safety, the aquatic science community has to anticipate emerging needs years, sometimes decades, in advance.

The purpose of this paper is to forecast the future of marine science in Canada. We first identify major new drivers of what the Canadian public will expect of aquatic sciences in 20 years (Section III). Some are consequences of environmental change and some of societal change, with the two, of course, intertwined in practice. Some "new" drivers have been around for a while, such as public concerns about biodiversity, but their impacts on marine science programs are only starting to be felt. They will be major agents of change in Canadian marine science in the coming decades. On the other hand, concern for environmental quality, protection of coastal ecosystems from marine industries and land-based pollution, climate change, and advances in technologies (biological, informatics, remote sensing, etc) are not listed as "**new**" drivers. Marine science in Canada has a long history of dealing with changing demands and expectations, and to the extent that resources have allowed, science programs have been adopting these issues since at least the 1970s. It is the new social drivers that may make resources for environmental sciences much more available, and thus may have great impact on Canadian marine science. Correspondingly, such opportunities are given prominence when consequences of new drivers are addressed.

The drivers determine the kinds of marine science that society will demand. These demands, in turn, determine the things that aquatic science will have to be good at doing in 20 years (Section IV). Contrasting the ways that aquatic sciences will have to excel in 20 years with what is done now will reveal the shifts in focus that will be required. For all but the final section, the Blue Paper concerns itself with marine science in Canada, not just in the Department of Fisheries and Oceans (DFO) or government. The final part of Section IV tries to consider the future role of DFO relative to its activities now, and to the roles of other federal departments and levels of government, aboriginal groups, universities, industries and non-government organisations, with regard to providing scientific information and advice in support of decision-making.

This document will serve as a discussion paper for a national science futures workshop. The workshop will consolidate views of the Canadian science community with regard to what changes will be needed in marine science generally, and particularly in DFO Science, over the next two decades. It will also commence the important second step of planning for making those changes happen.

II - BACKGROUND

Importance of Canada's Aquatic Resources

Canada contains hundreds of thousands of inland waterbodies, tens of thousands of kilometres of international maritime and Great Lakes coastlines, and one of the largest Exclusive Economic Zones (EEZs) of any country in the world, extending into three oceans. Canada's aquatic resources are fundamental to the quality of life in this nation. In addition to providing for the most basic needs, such as drinking water and other necessities of life, Canada's aquatic resources provide food, transportation, hydropower, recreation and processing water for industry.

Commercial fisheries landings are currently valued at about $2 billion, of which $83 million comes from freshwater. Recreational fishing in Canada involves about 20% of the population, and results in expenditures of over $6 billion. Canada's growing aquaculture industry has a total value of about $600 million. Not all resources are living; by 2002 the "landed value" of offshore hydrocarbons exceeded the landed value of commercial fisheries in Atlantic Canada. Canadians own 2.0 million recreational boats and spend about $2.0 billion annually on this activity. Commercial shipping contributes more than $ 1.1 billion to Canada's economy, and is growing rapidly. Comprehensive aquatic tourism figures are hard to obtain, but whale-watching in the St. Lawrence Estuary alone generates more than $100 million annually. To many Canadians, of course, the value attached to their aquatic ecosystems, for heritage, culture and physical and emotional sustenance, is not measured in dollars.

Scope and Role of Science

The marine science needed to support these industries and values requires knowledge of fisheries resources, aquatic ecosystems, navigation and human safety issues. Science's clients are diverse, including commercial and recreational fishing sectors, aboriginal peoples, shipping, recreational boating, ocean technologies, aquaculture, tourism, offshore energy industries, land-based industries that may affect the quality of aquatic habitats, environmental organisations and citizens concerned about their world and how it is used.

The Council of Science and Technology Advisors (CSTA) has identified the four roles of government-performed science and technology as:

- *support for decision making, policy development and regulations, for example, stock assessment, climate change, and sustainable development;*
- *support for public health, safety, environmental and/or defense needs, for example, the protection of fish habitat and endangered species and monitoring of toxic algal blooms;*
- *development and management of standards such as the resolution of trade disputes, genetically modified food, and organisms; and*
- *enabling economic and social development, for instance, sustainable aquaculture development.*

For aquatic science in Canada, DFO accepts all of these roles for government, as reflected in its Vision Statement, Strategic Plan and mix of programs. DFO does not fill these roles single-handedly. DFO joins in strategic partnerships and alliances with international science organisations, other government departments (e.g., Environment, Transport, Health), provincial agencies, the private sector, universities, aboriginal groups and non-government organisations. These roles will continue into the future, as the partners and partnerships adapt to changing needs and expectations.

Conspicuous in its absence from the CSTA list is the basic increase in knowledge and understanding that science provides to society. This role is crucial to Canada's entire marine science community. It motivates much of the science done within government, even when that work also addresses the other core CSTA roles. Moreover, the role is essential to Canadians. If knowledge and understanding are not being accumulated well in advance of the applied needs for them, science cannot fulfil the CSTA roles when called upon to do so.

Jurisdiction and Legal Mandate

DFO has responsibilities in legislation for protection and conservation of fisheries and fish habitat [Section 91(12) of the *Constitution Act, 1987,* and the *Fisheries Act*], pollution protection [*Fisheries Act*], management of activities in the oceans [*Oceans Act*] and many aspects of safe navigation [*Canada Shipping Act* and *Navigable Waters Protection Act*]. DFO's activities are also guided by acts such the *Canadian Environmental Assessment Act* and the *Species at Risk Act*, where other departments may have an overall lead, but DFO has a key role in aquatic ecosystems.

Correspondingly, DFO has developed or is in the process of developing many durable policies such as *The Department of Fisheries and Oceans Policy for the Management of Fish Habitat (1986)*, the *Atlantic Fishery Policy Review*, *Wild Salmon Policy*, *New Directions for Pacific Fisheries* and *draft National Freshwater Fisheries Strategy*, *2002.* All of these policies try to lay out structures for how DFO will deliver its mandate. Some other areas of importance to DFO are currently addressed through Strategy documents, such as the *Aboriginal Fisheries Strategy* and the *Federal Aquaculture Development Strategy*, which may evolve over time into more formal policies. In additional there are many bilateral and multi-lateral treaties, agreements, and instruments, such as UNCLOS, UNFA, the Pacific Salmon Treaty, NAFO, the Boundary Waters Treaty and many federal-provincial agreements, all of which further expand how Canada's aquatic resources and ecosystems are to be conserved and managed.

The legal mandate, policies and agreements are important for how DFO is aligned. However, in the context of a vision for the future of aquatic science, the important consideration is that science support in all the CSTA roles must be available to allow DFO to fulfil these responsibilities. Globalisation, both of trade and environmental threats, will mean that international science commitments will increase in the future. Twenty years into the future, the web of acts, international instruments, federal and departmental policies and strategies and agreements among various levels of governments will encompass even more issues. A constant, however, will be the need for a strong science basis to facilitate progress toward their diverse objectives, be it the objectives focused on sustainable use of resources, conservation of ecosystems and their components, safe navigation, national sovereignty or human health and safety. Society also may be more prone to legal challenges to government decisions, and to the science that contributed to them. Hence, the science will have to withstand challenges that are more frequent, partisan and direct than is typical at present. The task now is to envision the key features encompassed by the marine science that will be the basis for CSTA roles in the future, and how that science will achieve the standards that are necessary.

III – WHAT WILL BE KEY DRIVERS OF EXPECTATIONS THAT CANADIANS HAVE OF THEIR MARINE SCIENCE COMMUNITY?

1 – More Participatory Governance and Inclusive Science

Canadians will take as given the integrated, inclusive and consultative decision-making processes promised in the Social Union Contract, and embodied in Canada's *Ocean Act* and various co-management initiatives. The "integrated management" promised in the *Oceans Act* requires that factors be considered comprehensively when decisions are made about ocean activities. For at least three decades, the marine science community has tried to conduct and deliver integrated science to decision-makers. Efforts have been limited by resources and demands on time and people to deal with local and short-term needs. These constraints will not diminish in the coming decades, such that, on the "integrated science" side, we will at best have travelled somewhat further in a direction the science community has long been trying to go. How far we will have travelled depends crucially on what research resources are made available.

The bigger change will be that inclusive and integrated management planning approaches will be in place for all ocean areas. These will face several challenges, which have major implications for marine science.

These inclusive and integrated planning fora will not start out as level playing fields; some industries will have very deep pockets when they come to the table. Larger sectors will employ technical advisors full- or part-time to advance their interests, and a career stream of special-interest technical advocates will exist and make themselves available to smaller or less well-organised groups on an issue-specific basis. On the other hand, by working within these inclusive fora, community and special-interest groups will become better organised and more professional, and the public will express increasing risk intolerance for ecosystem disturbances, whether biological, physical or chemical. As a consequence, marine science will become the core input to these inclusive planning and decision fora, providing the common basis for subsequent dialogue.

Individual industries will have to be not just cognisant of, but connected to, the many other industries being addressed in the integrated planning and zoning of ocean areas for multiple uses. Potentially awkward fits between industry-specific regulatory boards and the inclusive, integrated decision-making fora is a governance issue, not directly a science one. Nonetheless, the numerous time-sensitive and sometimes contradictory demands of both groups for science support and advice certainly will be.

This decision-making setting will still have the federal government at its centre on marine issues, and many freshwater ones. However, government will no longer be viewed as the sole, or even primary, source of knowledge and interpretation from which consultation will flow. Rather, the empowered participatory groups will seek their science from whatever sources they trust and find most cost-effective. Government-based science will also encounter competition from diverse technical advocates who may come to the table with technical results styled to support the desired outcome that any of several competing interest groups. Some of these may reflect partisan bias, but all will be presented as "marine science". For government-based science to be supported in these inclusive fora, its products will have to be perceived as fully independent of pro-government policy bias. Likewise, its peer review and advisory processes will have to be widely inclusive, and survive scrutiny for bias by all sides.

This setting for inclusive, integrated planning and decision-making will require science, and particularly government science, to strengthen some existing roles in the decision-making process and accept some new ones, including:

- Science will have to know how to quantify, monitor and support management of cumulative effects of multiple impacts, and have the tools to do so;

- Science will have to know how to identify, select and apply effective mitigation measures when cumulative effects are stressing ecosystems, even if individual uses of the aquatic ecosystems are operating within sustainable boundaries;
- The peer review and advisory step will have to evolve from a largely in-house technical exercise, with primarily fishery applications, to a key step taken early in the inclusive decision-making process;
- Scientists will have to table their own analyses on a wider range of advisory issues. These will undergo “peer review” with more partisan technical experts at the table, and in competition with analyses from many other science practitioners;
- The inclusive decision-making processes will not simply accept technical contributions by government science as the best science available, unless those contributions actually can be demonstrated to be better than (i.e., not just equally as good as) the science available from other sources, and the science is structurally well-sheltered from Policy and political parts of departments;
- Science advisory meetings will have to be more responsive and reactive. Hypotheses possibly not of core interest to the science community will have to treated fully and seriously, if they are held by interest groups with leverage in the subsequent decision-making fora;
- Science advisory meetings will have to be more risk-management oriented, as the integrated management questions on which advice will be sought are going to be complex, with the relevant science incomplete and uncertain;
- With these meetings focusing on evaluation of consequences of alternative management options and competing uses, it will be recognised that the consequences hinge crucially on human behaviour and social and economic choices. Hence, more types of science, particularly social and economic sciences, will be part of the review and advisory processes. Partisan experts can differ in this area as well, and a common, objective factual basis will be needed for discussion on this aspect;
- The conduct of such meetings will be a complex and high-skill job, requiring special training, to keep adversaries at the table, and to avoid “negotiating” truth; and
- If such processes are effected and trusted, they will also be of substantial interest to the public, and hence under routine scrutiny by the press.

<u>2 – Demand for a National Climate Service</u>

As climate change alters our natural environment and lifestyles, and the ability to model the ocean-atmosphere-weather-climate relationships continues to improve, the public will demand better weather and climate forecasts. By the mid 2020s, Canada will have a **national Climate Service**, operated by an Environmental Ministry and functioning much as national Weather Services function now. These climate services will provide forecasts 3-10 weeks into the future with accuracy comparable in space and time to 4-7 day weather forecasts currently. They will also provide forecasts on time scales of seasons to a year or more with the generality currently obtained from 2-3 week weather forecasts. These forecasts will be important determinants of large scale and medium-term planning in agriculture, transportation and other weather-dependent commercial activities. They will have a significant role in lifestyle planning of civil society. Seasonal to annual forecasts will be important in public health and disaster preparedness. Predictions, such as extreme seasonal weather events, sea level changes, and ice conditions, will be provided as a basis for social planning, rather than as nearly hypothetical scenarios. The economic impact of the climate services will be very large, and their contribution to safety and quality of life of citizens will be larger still.

These forecasts will depend critically on operational models coupling real-time data on oceanographic and hydrographic conditions and forecasting models of future ocean conditions with weather and climate models that can do additional forward projections. The models will deal effectively with uncertainty through probabilistic forecasting. There will be strong competition for individuals with the expertise to interpret and refine the coupled ocean-weather and ocean-climate models and their probabilistic outputs.

Requests for science advice on how various ecosystem components will respond to forecasted climate and oceanographic conditions will increase in frequency, specificity and complexity. Agencies with regulatory roles (e.g., fisheries management, aquaculture regulators) will want to know how the resources for which they are responsible will vary in response to the expected conditions several weeks to several seasons in the future. Environmental managers also will want up-to-date information on changing risk profiles for contaminant distributions, oil spill trajectories and other hazards that are affected by ocean regimes. This means that there will have to be ecosystem models coupled to the operational climate models. A number of issue-specific “application modules” will also be linked to the Climate Service models, for tasks such as giving early warnings of harmful algal blooms, disease vector outbreaks, etc.

All these climate forecasts will be science-dependent, as will be the forecasts of the consequences of the predicted climate conditions. The forecasts will support so many decisions in nationally significant economic activities and personal lifestyle, that it will not be an option to withdraw, or have temporarily unavailable, the science functions. The science that will have to be available to meet such clients’ demands will include:

- A high density of individually low-cost, unmanned at-sea monitoring instruments will have to be in place, providing a high-density stream of remote data;
- Coupled ocean-atmosphere models will have to have been developed, tested, made operational and be running semi-remotely;
- Data integration, management and archiving of high density, high-volume data sources will have to be transparent to those using model outputs;
- Because the ocean-atmosphere-weather-climate models integrate across national boundaries, standards for monitoring and data management will be increasingly international, and the pressure to match capacity with our neighbours will be high
- Data and data products will have to be available in near-real-time to the climate and weather models and be readily accessible to those involved in further model development or applying the data in other ways;
- Well-trained expertise to develop and test such models and interpret their outputs will be readily available, although competition for such experts will be high;
- The availability of real-time, high-density integrated data sets on the state of the ocean and the atmosphere will allow the development of many new ocean technology industries and will have changed the approaches used by existing ones. These industries, in turn, will continually be pushing the limits of sensor capabilities, density, and processing time, challenging the instrumentation of the research and development community;
- The ocean industries will take full advantage of the spatial information in the data streams from the oceanographic and atmospheric sensors. However, to use the spatial information effectively will require that fine-scale, industry-standard ocean maps of bottom topography, substrate type and, in many cases, biological communities are available for Canada’s Exclusive Economic Zone
- Ecosystem modelling will be overburdened with demands that cannot be met with the specificity and reliability that clients will want, and the ecosystem modelling science community will be divided on both philosophical and operational issues (see Section III-3).

3 – Priority of Conservation of Biodiversity

Except in a few coastal areas highly dependent on fishing, **conservation and protection of the ecosystem and biodiversity will have become more important than fisheries** management as influences on public expectations of science. Science products will be of interest to and scrutinised critically by a wide range of stakeholders, including all whose livelihoods are based on oceans activities and public interest groups with strong conservation goals. A network of laws, international agreements and policies will have enough generalities and contradictions that demands for science support for decision-making in these areas will be difficult to satisfy. Quantitative objectives and reference points will be in place for some ecosystem and biodiversity properties, but additional measures will be regularly promoted by special interest groups.

A few themes, such as invasive species and recovery of species at risk, will exercise significant leverage in demands for science support and decision-making. The science agendas will be driven strongly by politically sophisticated interest groups. Much science will be reactive, and much will face severe partisan challenge, regardless of who does the science and who brings it into the decision fora (see Section III-1). Moreover, there are precedents internationally for species at risk controversies to become fraught with lawsuits and counter-suit, with "science" at the centre of the litigation. This will place Canadian marine scientists in roles that consume much time, resources and morale. So far, such situations have been uncommon in Canada (exceptions exist, such as Nechatko), but if they proliferate, they will require a much more conservative (which is not necessarily the same as conservation-oriented) approach to marine science.

Conservation of biodiversity necessarily requires working analytically in an ecosystem context, which in turn requires development and use of ecosystem models. In 20 years, the science community will have made breakthroughs in some of the components and parameters of ecosystem models that currently limit their use in applied contexts. Examples include transfer efficiencies among trophic levels -- factors that control primary productivity in oceans, the role and magnitude of the bacterial loop and further aspects of the decadal regime issue. Looking at precedents in terrestrial ecosystem modelling, however, there is no cause for optimism that there will be a scientific consensus on what are well-structured ecosystem models. Rather, there may be entrenched, and possibly divisive, views in the science community regarding competing ecosystem modelling approaches. Moreover, there is certainly no reason for optimism that such models can be parameterised reliably enough for their products to be trusted as a quantitative basis for decision-making. They will have an important role in exploring hypothetical scenarios and implication of alternative strategies for managing many ocean activities, but will not yet be the basis for operational control rules. Nonetheless, clients will want more from these ecosystem models than responsible scientists will feel they can provide.

The specific expectations on science in support of conservation of biodiversity will include:

- Although every year there will be demands on science to evaluate status of a few species being considered for addition to the list of Threatened and Endangered species, habitat designations and monitoring recovery of species already listed will consume much more science capacity than will evaluating new candidate species;
- If current recovery strategies and tactics do not produce swift and secure recovery of species for which Recovery Plans are implemented (and they have not for many depressed fish stocks), there will be pressure for significant research on recovery strategies and methods to allow commercial enterprises to proceed in areas frequented by listed species;
- The Canadian public will demand that the scientific community monitor effectively for the presence of invasive species, know how to detect their presence early, has effective mitigation measures for industries such as shipping, know what control measures to recommend when invasive species are detected and know how to implement these control measures effectively;

- Climate change will affect the distribution of many species, with at least two consequences for science. There will be public demands for hopeless efforts to preserve biological communities (and fisheries) whose environments are becoming unsuitable. Species adept at following their preferred environments to new geographic areas will become "invasive species" themselves, requiring scientific study to predict their impacts on the communities into which they expand;
- There will still be a lack of stakeholder consensus on desirable properties of ecosystem objectives and reference points (see Section III-5), and a lack of consensus among scientists about practical means for screening indicators and reference points to operationalise ecosystem approaches to management. This will lead to a great deal of science investment in "duelling models" and even more demands on the review and advisory system (see Section III-1);
- There often will be inadequate knowledge to identify management measures that move ecosystems reliably in the desired direction on ecosystem-scale objectives and reference points that are adopted. There will be many demands for science to fill these gaps and often pressure to conduct "populist science", which much of the scientific community finds questionable;
- Ocean and coastal maps and geomatics, including geo-referenced and ground-truthed geological, sedimentary and benthic plant and animal community information, will be a basis for many practices for the conservation of biodiversity, particularly for siting protected areas;
- Monitoring programs will have to cover all key ecosystem components, rather than focussing on a few exploited species, and extend into areas where monitoring (and supporting taxonomic expertise) is nearly non-existent, such as the deep sea and the Far North. International obligations may have a major impact on monitoring priorities and requires level of effort.;
- New observational methodologies and innovative applications of existing ones will be required, in order to monitor new parts of the oceans, and monitor at spatial and temporal scales not currently possible. Advances in genomics and bio-technologies will be prominent here;
- A better understanding of how ecosystem components fit together (e.g., predator-prey relations, environment-community interactions) will be needed to explain the status of ocean ecosystems and ensure their conservation. Ecosystem modelling will be essential in this area, but the diversity of modelling approaches poses a risk that the ecosystem modelling efforts will frustrate the search for this understanding more than they will aid it;
- Definition of "irreplaceable" units of biodiversity will be required to support species at risk and biodiversity conservation programs, necessitating increased capacity and new approaches in genomics, population genetics, taxonomy and systematics; and
- Scientists will be expected to define objectives for recovery of species at risk including population abundance and distribution objectives and critical habitat preservation objectives. This will require enhanced work in population dynamics of groups currently not well-known and in habitat-species interactions.

<u>4 - Emergence of Social Sciences as a Complement to other Marine Sciences</u>

The social sciences will be an accepted source of knowledge for conservation and management of aquatic resources and ecosystems. The steps made so far in using "traditional ecological knowledge" (TEK) to augment the natural and physical sciences as sources of understanding of ecosystems will be replaced by a major cultural shift. Social scientists will initially be approached primarily as a tool for accessing knowledge held by resource users, to complement results of the biological and physical sciences. Once the linkages are built, however, the impact of social sciences on decision-making will grow. Formal anthropological, sociological and economic studies will be part of evaluating the consequence of management actions being considered. There will be growth on all three fronts of the marine social sciences: human behaviour of resource users and coastal residents, determining what is "best use" in integrated management contexts, and how (and how much) communities can adapt to consequences of management options. Such knowledge will allow implementation uncertainty to be treated in the same framework as model and parameter uncertainty. It will also provide a more comprehensive and better quantified understanding of the social and economic consequences of alternative management choices. Such knowledge and understanding will result in more informed management choices, and be welcomed at the integrated, inclusive decision fora (see Section III-1).

Once social sciences are integrated with the biological and physical sciences, the nature of marine and freshwater science will include:

- Science Sectors of government will include sociologists and anthropologists; economists in Policy Sectors will do research as well as summarise and interpret statistics;
- Science review and advisory meetings will evaluate routinely the likelihood of compliance and other human factors related to consequences of policy options, and advice provided at the meetings will include analytical treatments of implementation uncertainty just like the other types of uncertainty;
- Resource users will participate in forming and testing hypotheses, not just in monitoring attributes of resources and ecosystems;
- Co-management will not be a concept, but a routine way of doing business throughout Canada, as it is now in parts of the North;
- The trait that at least some "schools" of social sciences reject the concept of value-neutral science as even possible, let alone desirable, will continue. The presence of well-credentialed social scientists, presenting their work in advocacy of particular policy alternatives, will have reinforced similar tendencies in the field of "conservation biology" to create a much more partisan debate about the application of all science results to conservation and management choices.

5 – Adopting Objective- and Reference Point-based Management

Management of uses of ocean resources will be risk based, and structured around quantitative objectives and conservation reference points. The Precautionary Approach will have evolved substantially, but the concepts of being risk averse relative to reference points associated with serious harm to the resource and ecosystem, and basing decision-making on pre-agreed control rules will be entrenched in management practice. Suites of industry-specific objectives, reference points and control rules will be developed for key ocean uses, such as fisheries and energy exploration. However, some key ecosystem-scale objectives and reference points will be applied across industries, with the integrated management fora described in Section III-1 being the places where responsibility for achieving shared objectives and complying with reference points is allocated among different sectors.

Fisheries may feel the effects of this driver most directly because, where these practices have not been adopted, the fisheries will have failed, due to the inability to scale down harvesting swiftly enough when the resource begins to decline. Professionalisation of commercial fisheries will be the norm, and the needs and rights of aboriginal peoples will be addressed comprehensively. Individual Quota (IQ) management will have spread widely, although where appropriate the quotas may go to communities or other entities, rather than to individuals. However the IQs are allocated, there will be substantial impacts on coastal communities, as participation in fisheries will have become much more restricted but much more profitable. One of the follow-on consequences will be that for many fisheries most costs for monitoring, research and assessment will be borne by the participants, and monitoring data will be reliable. Objectives addressing ecosystem effects of fishing, particularly with regard to bycatch and gear impacts on habitat, will have substantial leverage in decision-making

The positive scenario for such fisheries still will be occasionally undone by short-sighted, employment-packing initiatives. The inability to control effort proactively in the booming recreational sector will continue as well. Both tendencies will continue to force management to be reactive and slow effective response to resource downturns. Environmentally driven variation in resource productivity will be either the same or greater than at present. Consequently, resource crises will continue to be common in a disproportionately small number of fisheries, but they will continue to dominate public debate and government actions in fisheries and draw heavily on science capacity.

Objectives, reference points and control rules will work comfortably in some ocean industries and present real challenges in others. Management of contaminants in this framework, for example, will present serious challenges. The public will be exceptionally risk-averse relative to the presence of contaminants in marine ecosystems and to their ecosystem consequences. Hence, objectives and reference points will be stringent and under frequent scientific challenge as diagnostic tools continually improve. The science community will face even greater challenges in setting suitable control rules for these threats. Sources of pollutants may be land-based or otherwise far from detection sites, and effects may only be manifest with long delays or as a consequence of bio-accumulation through several levels of ecosystems.

The nature of science supporting Objectives-based Management in this setting will include:

- All assessments will focus on quantifying stock and ecosystem status relative to reference points, using stable, structured analytical approaches. Regular (but not necessarily annual) assessments will be as much a part of evaluating and managing other ocean industries as they are of managing fisheries at present;
- Components of core assessment work, particularly but not exclusively monitoring, will be done by many different sectors, depending on who offers the payer the best value for money. Government will play an audit, consolidation and data archiving role, but it will not be a given that assessments will be done by scientists working for government;
- Assessing ecosystem status relative to ecosystem indicators and reference points will be as routine as assessing status of individuals stocks, but single-species assessments of stock status will have increased in number rather than decreased to support IQ management needs;
- Developing and testing control rules for ocean uses (including, but not limited to, fisheries) will be a key responsibility of the marine science community;
- A higher-level audit system will exist to deal with risks (and perceptions) posed by science funding being closely controlled and directed by the industry that is supposed to be regulated on the basis of the science;
- Where fisheries are professional and entry restrictive, the inclusiveness of how science and assessments are done and reviewed will lead to products of high credibility and leverage on decision-making;
- Where fisheries are employment sinks or effort cannot be regulated, science will continue to be distrusted and contested, and practitioners will operate within either an advocacy or a siege mentality;

6 – Opening of a Navigable Northwest Passage and Greater Development in the North

By the mid 2020s, warming of the Far North will have resulted in a **Northwest Passage that is navigable for several months a year**. When such a passage exists, there will be significant shipping through the passage. At least a portion of this shipping will pose environmental threats because high-risk cargoes (e.g., toxic substances, petrochemicals) unwanted off populated shorelines and container vessels too large for the Panama Canal will be encouraged to take the northern routing. Such shipping will pose additional risks of harmful interactions with marine life, particularly migratory marine mammals. Faced with the risk of challenges to Canadian sovereignty and security in northern waters if we do not exercise the actions expected of a responsible steward of Home Waters, Canada will accept but regulate such shipping.

Population and industry in the North will both grow, with all the environmental risks of industrialisation and urban growth in other parts of the Canada. However, arctic marine ecosystems, fragile to begin with, will also be under added stress due to climate change. Hence the demands for science support for decision-making and regulation will be even more urgent than elsewhere.

The science that will have to be available for the interests of Canadians and the Canadian environment to be protected includes:

- Reliable electronic charts and navigation aids will have to be available for the main shipping channels in the North, and for alternatives to which ships could be directed when emergencies or anomalous conditions make the main routes unavailable;
- Approaches to alternative deep-water service ports will have been fully charted, and environmental assessments conducted and reviewed for these sites; both navigation tools and information in environmental impact statements will be updated regularly;
- Baseline biodiversity data will have to be available for the areas through which shipping will pass, as reference benchmarks for evaluating potential effects of increased human activity;
- Monitoring programs will have to be in place for major components of biodiversity. Their goal will be to ensure anthropogenic perturbations can be detected and differentiated from the many range expansions that will result from the same climate changes that opened the passage. This goal will rarely be achieved;
- Places with minimal risk for ballast water exchange will have to be known and publicised – which, in turn, implies science will have to be able to characterise places where ballast water can be exchanged safely;
- 2-D and 3-D current and transport models will have to be operational and tested, such that spill trajectories can be rapidly simulated when spills or other emergencies occur. These models will have to include or be linked to other bathymetric and oceanographic features such that they also meet navigation and transport needs;
- Mitigation and clean-up technologies appropriate for dealing with spills and accidents will have to be known, and the necessary technologies will have to be on call.

<u>7 – Demand for Near-real-time Access to Data by Canadians</u>

Advances in participatory democracy (see Section III-1) and electronic communications and networking will mean that **the public will expect full- and near-real-time access to the data and information holdings of government**. Such data and information holdings will have to be fully integrated, quality controlled and readily navigated. Technical experts from many sectors will expect access to comprehensive data sets, whereas civil society will expect equally ready access to information products that integrate the different types of data into forms that they find sufficiently impartial and informative to serve their needs as participants in governance. All these demands for better access will have to be accommodated in a setting where technological advances are continually expanding the ability to collect information on more components of the ecosystem, and with greater spatial and temporal resolution.

For science, the impacts will include:

- As fully as possible, data recording will be automated, with quality assurance/quality control (QA/QC) steps built into the initial processing. These steps will be conducted in ways that result in data being on-line in near-real-time;
- In addition to actual data sets, data products reflecting some degree of processing and aggregation will be completed and accessible as quickly as possible given the nature of the individual products;
- Maintenance of user-friendly websites serving as portals to effectively-archived data sets and particularly the data products will be a priority for governments, both as basic outreach and because their sites will be in competition with sites owned by partisan groups offering similar products, but with presentations intended to sway public opinion rather than inform it;
- Some data sets, for example those regarding navigation, will have a serious liability component, increasing pressure on science contributors for both timeliness and reliability;
- Integration of data sets and data products will have spread back to integration of monitoring programs, where international obligations and standards will be influential;
- Where monitoring is shared or led by private sector groups, government's audit and QA/QC roles will be particularly important;
- There will be continuing demands on those providing the data bases to build public capacity to not only access data and information, but use it effectively. This means information providers, including governments will have to develop education components to accompany their provision of information ;
- Access to many of the data sets of greatest interest to the public will have to respect personal privacy and corporate proprietary considerations. A new class of data managers, skilled at balancing the right to know with rights to privacy, will have to be engaged in setting up and monitoring data access practices.

8 – Extensive Mariculture of a Core of Native Species

Many stocks that supported important commercial fisheries in the 1960s to 1980s were depressed by the turn of the century. Recovery of most of these stocks will prove very slow, and long before most will reach historic abundances (and yields), harvesting opportunities will be given priority over further rebuilding. New fisheries, and fisheries on stocks that had not collapsed, will have to operate at much lower exploitation rates, such that total production from capture fisheries will be low in volume and employment (although not necessarily total value) compared with the last decades of the 20th century.

Failure to recover depressed roundfish and flatfish stocks will be offset by **large escalations in aquaculture production** of several species of white-fleshed roundfish and shellfish. Improvements in knowledge of culture methods, sustainable practices in an ecosystem perspective and bio-genetic engineering will have allowed cultured native species (e.g., cod and haddock on the East Coast, prawns on the West Coast) to fill major market niches seeking replacement for lost harvests from wild stocks. Technology will have advanced for both coastal and offshore culture, presenting the double edged potential of both greater production and greater ecosystem impacts. Science will play a crucial role in finding a sustainable balance here.

Impacts on science will include:

- Bio-genetic research and development in support of a variety of aquaculture applications, including improving broodstock traits such as growth rate, flesh quality and disease resistance, will become routine;
- Guidelines for site selection, development and culture practices will exist, based on a large body of multi-disciplinary research on sustainability of culture in ecosystem contexts;
- Effects monitoring of aquaculture facilities in coastal areas will be standard business practice in the aquaculture industry, with clear standards and independent peer review of monitoring results and advice on the need for mitigation actions;
- Private sea-ranching may become established as a economically viable practice, creating new science requirements for product development and effects monitoring;
- Research on health and safety to consumers and consumer acceptance of genetically-modified or artificially-selected fish lineages, and of fish treated with pharmaceuticals, will be a greatly expanded field of scientific endeavour;
- Increasingly stringent rules on introductions and transfers will have motivated significant advances in strategies for bringing local strains and species into culture quickly.

9 – Attention to Reducing the Gap between the Global North and South

The economic gap between North and South will have reached such a size that Canada, along with many other developed countries, will finally come to treat equity and capacity building in under-developed countries as a priority. Whether motivated by conscience, desire for justice, interest in global ecosystem integrity or fear of terrorism by the disadvantaged, much science effort will be devoted to sharing knowledge and technology with less economically advantaged states. Some of the brighter people involved in this work will see that the North has as much to learn from the south they have to teach. We may find that we are trading Northern scientific tools and technology needed by the South for a wider range of concepts about management and ecosystems, equally badly needed by the wealthier North.

The limited capital (both financial and infrastructure) available to many parts of the South will place a premium on low-tech solutions to many science and management problems. Research and development focused on these approaches to problems will be given some priority in science, and will be found to pay off well domestically, as well as in international settings. Research will focus on needs of commercial fisheries where capacity is limited for directed science on the biology of the target species, ecosystem effects of fishing, effectiveness of management alternatives and artisanal and subsistence fisheries. The link of land-based activities to coastal ecosystem health will also a key priority area, where the use of community values and structures to address multiple-use problems may move usefully from South to North, even as technical experts from Canada build capacity to monitor and diagnose problems.

The implications of this more serious attention to research and capacity building in the less-developed countries will include:

- Most scientists will be expected to contribute some period of time to work in development projects and/or developing countries;
- Science funding will come from many non-traditional sources as diplomatic and national security priorities come to affect patterns of distribution and magnitudes of science funding;
- The needs of subsistence hunters in Canada’s North will become a very special and high priority, as climate change make tradition methods and places for hunting marine and freshwater resources no longer practical;

- The integration of social sciences with other marine sciences in Canada will be facilitated by the experiences of Canadian science experts going on missions to build technical capacity in the South.

IV - GIVEN THESE DRIVERS, WHAT WILL MARINE SCIENCE IN CANADA HAVE TO DO DIFFERENTLY OR BETTER THAN AT PRESENT?

We can see some science activities that currently struggle to find support but in 20 years will be major science foci.

A. Science Certification and Audit Processes

The performance of science will not be monopolised by academic and government professionals. Many individuals and groups, in many settings, will be conducting components of research and monitoring. They will be welcome, because industries will be expected to cover more of their own management costs. They will be essential, because effects monitoring will be required for more ocean industries, and relative to a wide array of specified objectives and reference points. They will see the opportunities, because objectives-based management and application of control rules will make key parts of the science more systematic and orderly, even for the professionals. **The professional science community will have to develop the techniques, institutions and traditions of setting performance standards for diverse science activities, and for auditing performance against them,** while the *doing* of science will be more of a populist activity**.** This process is already developing in a few areas of applied science and technology. Examples include the ISO 9000 process for certification of technological processes, and the Marine Stewardship Council eco-certification process for sustainability in prosecution of fisheries.

The above examples may be good models of how performance standards are established and performance is audited, but the science community will have to think much more widely about how to certify science activities done by communities, special interest groups, corporate entities and civil society. The inclusiveness promised to citizens by government and on-going fiscal constraints faced by traditional science institutions in academia and government both ensure that many parts of society will be doing activities that they consider to be scientific. The increasing democratisation of decision-making means these groups will expect to be able to contribute their results as part of the scientific foundations for informed decision-making. It will be impossibly burdensome for the professional science community to deal in an *ad hoc* manner with each request for advice or technical support from a group with a science or monitoring activity it wishes to pursue. Dealing with each contribution from such groups to decision fora in a reactive manner will foster an adversarial relationship between the professional science community and both the public and private sectors of society. Formal certification and audit processes designed to for broad application will simplify (but not fully eliminate) both of these undesirable potential developments.

B. Centrality of Structured Review and Advisory Processes

When conducting science will no longer be the property of "experts" with a narrowly defined set of credentials and decision-making will be broadly inclusive, there will be the risk of as many "facts" and "scientific interpretations" as there are perspectives among sectors of society. Special interest groups from many perspectives will have become very sophisticated as presenting biased "technical analyses" of bodies of information as if they are presenting sound science. On the other hand, high quality science done by partners who take profit from activities in the ocean will be vulnerable to attack solely because the partners are perceived to be in a conflict of interest. To avoid moving to a situation where every decision is preceded by a period of adversarial debate, accompanied by special interest leveraging of decision-points and followed by litigation, there will have to be formal processes for peer review and provision of scientific advice. These will have to be treated as a *necessary* step for screening the technical contributions of all groups, as a pre-condition to allow any "technical analyses" to be accepted as part of the factual basis for discussion of options. The peer review and advisory processes will also have to be perceived as *completely impartial*; a forum where the technical legitimacy of analyses and interpretations are evaluated on a level-playing field, regardless of their source, and industry partners will receive as fair a hearing as government and university scientists.

These structured processes will not resolve the debate about *interpretation* of fact, whether based on different values or simply different priorities. However, if the different interpretations do not at least flow from a commonly acknowledged corpus of scientific information, the whole notion of rational risk management in governance will be lost. Therefore, for science to be effective in supporting decision-making, those who do not come to the common review and advisory table have to become marginalised in subsequent steps.

The centrality of these processes as the node between democratised performance of science and the application of science products to decision-making means that the relationship between these science-centred review and advisory processes, and the policy and management portions of government, will be extremely sensitive. They will have to be seen to be independent and nearly infinitely patient with diversity of perspective and skills. Simultaneously, they must remain exceptionally well-focused on the information needed for the decisions to be made, and provide timely products in a world of accelerating pace.

C. <u>Data Integration and Management</u>

The marine science community has shown it can be very good at data management and integration, but our greatest successes are in comparatively homogeneous fields, such as physical oceanography. This field provides a good model of what is needed broadly, but progress elsewhere has been slow. Individual initiatives to integrate and provide ready access to government holdings in biological and fisheries data have shown promise, including the Fisheries Management Information Systems Study Team in the Pacific Region in the early 1990s, the Virtual Data Centre in Maritimes Region and the St. Lawrence Observatory in Quebec Region. Even more ambitious initiatives across government, academia, and some public interest sectors are in early stages, such as the BioSystematics Foresight Project and the Centre for Marine Biodiversity. To this point, though, the smaller initiatives suffer from limited resources and challenges in scaling up from pilots to comprehensiveness. The integrative initiatives are largely untested, and the planning documentation is short on details in some programmatic areas. Some excellent data integration initiatives, such as the Atlantic groundfish survey database, present challenges in keeping up-to-date once created. The price tag of fully costed, truly integrative and comprehensive data integration and archival systems, such as the "Data Treasures at Risk" initiative by the U.S. National Oceanic and Atmospheric Administration (NOAA), is staggering.

Technological advances continue to outpace the patchy track record for full data integration and management. Tools for displaying, overlaying, and using spatial data sets are becoming more powerful, and more widely available. Data transfer is ever-faster and more reliable; remote sensing technologies denser in space and time. New sensing instruments are increasingly intelligent. Perhaps most importantly, new generations of Canadians are completely at ease seeking and using diverse information sources; new industries demand them.

Although government will have to network with many partners who provide input and use products, it will have to lead the creation and maintenance of the integrated data sets. The public will demand it, both as a part of good governance, and because private sector control of major data sources will be both unacceptable and unaffordable. However, the very integration required for important data sources will mean departmental boundaries within government will be largely irrelevant. Weather, ocean and climate data will have to appear transparently integrated to diverse users. Information on the sea-floor and water column will be integrated with biological resources, economic undertakings, energy sources, transport and planning tools.

Even partial or temporary failures in provision of these information sources – whether the failure is system downtime or poor quality data – will have social and economic consequences that, in some cases, will be so serious that they will result in liability claims. Protection of privacy will be an important issue, requiring policies and practices to be upgraded greatly. By contrast, jurisdictional squabbling within government, whether within or among departments or between government and its partners, will find no sympathy in the public and private sector viewpoints. We have a job to do, and Canada wants to see us get on with it.

D. <u>Indicator-based Status and Trends Monitoring</u>

Canadians will want to be assured that marine ecosystems as a whole are being conserved, and will expect the marine scientific community to inform them regularly about the state of much more than just major commercially harvested fish stocks. Logically, the information the public receives from the science community will be integral to their views and positions in the more democratised decision-making and integrated planning fora. These fora will deal with integrated coastal planning, mitigation of cumulative effects, harvesting multiple commercial species, managing bycatch, evaluating impacts of energy and aquaculture projects, recovering species at risk and diverse other tasks. The diversity of priorities and interests of the participants mean they will demand a consistent basis for information on status and trends. They will want this information in ways that inform decision-making; not highly sophisticated analytical models of population trends of a few species and speculative narrative on all other ecosystem components. Nor will "soft" ecosystem model results, predicting either abstract ecosystem properties or only general trends for groups of species, prove adequate for building consensus in these settings. This will mean tracking the status of a broader range of species than at present and a number of concrete ecosystem properties.

Keeping the length of such monitoring "wish lists" tractable will be problematic. Resource limitations at all phases of science, from monitoring to analysis, mean that the science community cannot raise the standard of comprehensiveness of all the information it provides to match the standard of its best analytical assessments at present. For many ecosystem components of interest, in fact, the very nature of what needs to be reported will not fit readily into practices developed for current single-species fish stock assessment. However, fisheries practice is becoming indicator- and reference point-based, and that approach maps well onto the much broader reporting responsibility expected of the science community. This will be the common ground for evaluating success in achieving management objectives, whether for a single exploited fish stock or a major ecosystem property, and regardless of the human activity being managed.

When indicator- and reference point-based reporting of status and trends becomes the norm, however, much attention will focus on the selection of indicators to use. The science community will be continuing to strive for a balance between new indicators which take advantage of scientific advances in fields like biotechnology and remote sensing, and indicators well understood by those who will be regulated on the basis of the indicator values. Just a few unfortunate experiences with decisions based on uninformative indicators chosen because of theoretical attractiveness, convenience or popularity, instead of quantified information content and tested reliability, will create the demand for performance criteria for indicators and rigorous screening of alternatives. This will be a new and demanding task, even if the indicators and reference points produced by it make subsequent assessments and reporting more tractable and orderly.

E. Developing and Testing Mitigation and Recovery Strategies

Science experts will be expected not just to detect that some activity is at a level that is no longer sustainable, but also to fix the problems caused by the activities and advise on how to avoid future problems. The *Species at Risk Act* foreshadows these expectations by requiring that programs be actively pursed to recover species designated at risk. The poor track record of rebuilding fish stocks on the East and West Coasts are becoming a rallying cry for critics of current recovery practices, rather than just an embarrassment. Government, academia and the private sector already have some success stories in habitat restoration. However, these stories are examples of dedicated work by committed teams, not proof that such work is a consistent priority, nor that the science community has all the management tools it needs to be confident recovery targets will be reached.

Demands will escalate for systematic progress in design and implementation of strategies to mitigate environmental damage, recover depleted populations and protect ecosystems from invasive species. A diverse field of technical experts will evolve, who have flexible tools for both responding to emergencies and rehabilitating damage. These tools will not be activities undertaken as research projects or showcase examples. They will be routine activities for multidisciplinary teams of government scientists and their partners in academia, non-governmental organizations and the private sector, involving habitat restoration, protected areas, population manipulation, changes to industry practices (e.g., selective fishing) and novel methods whose nature will emerge from future research. A supporting research community, focused on developing and testing new and better tools, will evolve as well. New technologies, particularly bio-remediation technologies for contaminated sites, will need to be developed to operational states. Extension offices, teaching best practices to industries working in the seas, will also develop.

F. Expanding Knowledge of the Seafloor

Knowledge of the seafloor will be essential for supporting diverse ocean industries, conservation of biodiversity, and even routine fisheries management. Ocean industries will use the information prospecting for opportunities dependent on the structure and composition of the seafloor (e.g., mining, energy), for planning operations in ways that do not have unsustainable impacts on the marine ecosystem and for more efficient and safer transportation of goods and people. Conservation of biodiversity will use knowledge of the biotic communities as a core component of the inventory of biological diversity, and of the abiotic structural component as a core aspect of marine habitat quality. Science in support of fisheries management will use the knowledge of the seafloor as a guide to system productivity and as a key covariate to interpreting both commercial catch and research survey data.

Many parties will participate in the collection of these data on the biotic and abiotic components of the seabed. Several government departments have overlapping mandates and interests that will guide their roles, whereas the direct commercial interests in the private sector, and the conservation interests of the best-supported environmental non-governmental organizations may make different groups focus their efforts on collecting or interpreting data on particular components of seabed characteristics. Government will play the key coordinating role among partners and will ensure that the maximum return for investment can be recovered when costly ships or other platforms are made available for work in any specific area by promoting collection of as complete and varied an array of data as possible. Government, too, will have assumed responsibility for much of the data integration and management and for ensuring compliance with industry standards. Were data management under private sector control, the public accessibility of information about the oceans may not be assured, and the government itself might have to lay out substantial money to access the very data it was instrumental in collecting.

G. Developing New Ocean Industries

The development of ocean-related industries has at least three major stimuli. One is the marketable advances that arise from research to increase the capabilities, durability, speed, miniaturisation, life-span and density of remote-sensing and semi-remote-sensing instruments. The second is the new commercial opportunities that arise from availability of much more extensive and more integrated databases on the geology, seabed, water column, biota, ocean chemistry, ocean physics and meteorology. The third is the favourable business environment that will arise from well-integrated and inclusive decision-making, with social sciences helping to ensure community and coastal identities and values are clear and considered reasonably in planning.

Speculating on the exact nature of these new industries would be fool-hardy, because many of the most influential commercial developments 20 years into the future will be important just because at most a handful of people see their potential at present. However, bio-technologies, particularly marine pharmaceuticals and bio-remediation methodologies, and instrumentation for durable operation under harsh environments look especially promising at present. Whatever the nature of the industries, there are several clear implications for science. One is that the private sector will have a much greater role in research and development, from development of instrumentation and research on fish health and culture to inventories of ocean biodiversity, seabed features and other resources. A second is that tolerances will be very small for failure to keep data streams available on a real-time or near-real-time basis, with high standards for QA/QC, and for value-added syntheses, because such failures could have major impacts on corporate performance. This will be particularly true in ocean-climate services areas. A third is that whereas government may be a minor partner in the actual research and development, it will be the key focus for planning, auditing and effects monitoring. Working with the inclusive and integrated decision-groups, government will be the neutral host for meetings where the sustainability of the ecosystem and community impacts of these industries are evaluated and multiple uses are reconciled, through zoning and other means.

H. Building Bridges to Social Sciences

Civil society as a whole, and partitioned into diverse corporate and public interest groups, will play a much greater role in both governance and marine science. Moreover, it is becoming more widely acknowledged that many past failures to achieve sustainability in fisheries management came about because of implementation uncertainty. Science and management were trying to achieve the right bio-ecological management objectives, but they understood too little of how to modify the activities of those prosecuting the fishery in ways that would achieve those objectives. Finally, needs for information on marine ecosystems already exceed the ability of Canada's science community to deliver, and these needs will grow much faster than science capacity. The knowledge produced by the science community has to be augmented by the extensive knowledge of many types of people associated with marine ecosystems.

All those developments foreshadow substantial collaboration of the natural and physical marine scientists with social scientists from many fields, including economics, sociology and anthropology. The marriage of disciplines will be preceded by a difficult courtship, because there are pre-conceptions to overcome on all sides. Once the disciplines are working together closely however, many things will improve. Science will inform and advise participatory governance more effectively. Management tools will change in ways that make them more effective as well. Economists in government and universities will conduct more complete cost-benefit analyses of management options, where both costs and benefits are quantified in ecological, social and fiscal terms. A larger information base, reflecting both users' and scientists' knowledge, will speed advancement of understanding marine ecosystems and their uses, and improve ability to support decision-making.

I. Doing Science in the North

Canada's northern marine ecosystems and resource users will face mounting pressures, and our failure to invest in research in the North over the past decades will haunt us. Navigation, sovereignty and security activities, and industrial development will multiply greatly the opportunities for environmental disasters. Climate change will affect living marine resources of the North as well as the subsistence hunting techniques of Northern peoples who rely on them. Biodiversity, already comparative poorly inventoried and poorly understood in the North, will be altered by changing environments and the expansion of species' ranges from the south. Threats to biodiversity components will increase as human activities in the North increase and diversify, and expanding species attract commercial interest from fisheries.

A very few environmental disasters due to industry or transportation errors that could have been prevented with better knowledge, or the loss of even a few conspicuous components of northern biodiversity or aboriginal culture, will be perceived by all Canadians as a major failure of their science community. We have to avoid those failures. The science community will *have* to work in the North. Science commitments will have to be serious, integrated and long-term. Strengthened partnerships will be essential among all science interests, between science and industry, and between the science community and Northern peoples.

IMPLICATIONS FOR SCIENCE IN DFO

What do these new areas of science focus imply for science in DFO? **Without question, DFO Science will still be doing original and creative science, to increase knowledge as well as to apply science to management.** This role is necessary if we are to have the expertise to even set monitoring and auditing standards, conduct peer review, or apply knowledge to Canada's interests in the ocean. It is essential if we are be an attractive employer to the best and brightest of future generations of marine scientists. However, there are widespread concerns about *how much* science will be done in DFO for discovery of new knowledge, rather than just application of existing knowledge to the problems of the day. Moreover, **beyond continuing to do world-class science and supporting decision-making in fisheries and increasingly in oceans management, we have to consider a number of challenges to the *status quo*. Some key ones include:**

1. The science done in government will be conducted much more with teamwork inside and partnerships outside. The partnerships will be with much more diverse types of collaborators

locally, nationally and internationally. There will be more competitors in the pool of candidate researchers – competing for research support and for the confidence of the public – so DFO researchers will have to respond rapidly to opportunities as they arise. Much less duplication of expertise will be supportable across centres, and centres will have to be highly flexible in sharing expertise. Science done in government will be under much greater scrutiny and subjected to greater partisan criticism. If it is to be credible, it must not only be of highest quality, it must be well separated from policy sectors of government. It must be highly policy *relevant* in the problems attacked, but readily seen to be un-biased by policy considerations in the approaches taken and answers provided.

2. A core role of DFO Science will be providing settings for peer review and application of science conclusions as advice, rather than doing most of the marine science of Canada. If we earn it, we will be looked to as *the* place where competing interpretations are evaluated and balanced fairly among a truly diverse mix of expertise and backgrounds. There will be a new, applied science career path of running such meetings effectively.
3. In areas where we want to *do* the science, we will have to work much harder than at present to show a sceptical public that we do it most cost-effectively and/or that the public interest is best served by having the science done within the public service.
4. DFO Science in support of management decision-making will be structured around choosing effective indicators and reference points, and then evaluating risk of management options within that framework. This will require a cultural change from trying (and failing) to know everything about each science issue. It also will require changes in culture in other parts of DFO to deal with science advice that will fit most naturally with rule-based decision-making.
5. Much science will be carried out outside not just government, but academia as well. In areas where private sector or public interest groups play a major role in monitoring (or research) DFO Science will have to take on a new identity as the place where quality standards are established for data collection and processing and which audits compliance with those standards. These will be high-impact but low-glamour jobs, requiring both high-level disciplinary knowledge and tact. Aquaculture and fish health may be one of the first areas to complete this transition of role.
6. Data management will be a much more conspicuous part of DFO Science's responsibilities. Structured processes for quality control, integration, providing value-added products, and building and maintaining user-friendly portals will be a costly but essential part of all of DFO Science, as they are now for Marine Environmental Data Service.
7. Coupled ocean-atmosphere and ocean-climate models will be operational tools (although researchers will be upgrading their components and capabilities regularly, and investment in instrumentation will have to be a large, ongoing commitment.). However, providing and interpreting the outputs, and helping to apply the outputs to a huge array of other departmental, governmental and societal needs will be a new and rich career stream, much as the weather *service* employs more scientists and gets much more attention than the weather *research* community. This new career stream could be diffuse within government, but if DFO does not seize some of the opportunities here, we will become marginalised as little more than a data provider.
8. Collaborating effectively with social scientists will be a challenge to the DFO Science culture at present, but one we will have to meet. Direct linkages to the social sciences will be needed in addition to whatever indirect ones are established through Policy, Oceans or Fisheries Management Sectors, although multi-sectoral partnerships would certainly offer great potential. DFO Science would benefit greatly from having social scientists employed directly in the Science Sector, but experience elsewhere has shown that a critical mass of that speciality, like any other, is essential for effective work. A token sprinkling of social scientists is pointless, and if that is the only hiring possibility, formal collaborative arrangements with academic centres would be superior.

9. Hydrography and oceanography will have to find ways to work at a more significant level in the North. Failure to commence such work within the next 10 years is a recipe for disaster. On the scale of a decade to a quarter-century, this will be a much wiser risk-reduction strategy for DFO and government than focusing on services to recreational boaters near population centres.
10. One growth area of DFO Science will be to first develop flexible and effective mitigation and recovery strategies and subsequently adapt them for case-by-case applications. Many science and community sectors will deliver programs based on the strategies, but government will be expected to create them, and to guide how they should be applied.
11. We will have completed mapping of the ocean floor, its bottom characteristics and key water column attributes. These maps will need maintenance and updating like any other chart.
12. DFO Science staff will be required to change both research emphasis and geographic locale more often through their research careers. Experts will be expected to contribute substantially to training and capacity building of many Canadian groups outside government, and return regularly to audit performance. Staff will also be expected to accept assignments in the developing world.

These challenges will stress our ability to adapt and to preserve our strengths while building new ones. Building those strengths will require adding or augmenting several scientific disciplines to our ranks, or forging strong linkages to them if they work in academia or the private sector. These include:

1. Taxonomists and general ecologists to deal with biodiversity issues and indicators of ecosystem status. The need for experts in the Arctic and deep seas is particularly great;
2. Social scientists: economists, anthropologists, sociologists, and others;
3. Data managers, who know scientific disciplines, information technologies, and can reach the public effectively;
4. "Mitigation and recovery scientists" who combine knowledge of species, habitats, population dynamics and ecosystems with understanding of various industries;
5. Quantitative experts and good modellers will remain a priority, particularly ones who are broadly multi-disciplinary, work well in teams and can communicate results to diverse audiences;
6. Chemistry, biochemistry, and molecular biology expertise will be needed to deal with may issues in biotechnology, aquaculture and associated fields
7. Skills in running review and advisory meetings, and being the science advisor to the inclusive, integrated planning and decision groups, will be needed;
8. Almost every speciality working in DFO Science can make a strong case that it is under-staffed relative to current expectations, and incapable of dealing with additional future expectations. They are probably right.

VI - HOW WILL WE MAKE THESE CHANGES, AND OTHERS LIKE THESE?

The Blue Paper does not have to answer that question. It is for the rest of the Futures Exercise, and DAA, to decide *how* change will occur. This paper is just intended to stimulate the dialogue on *what* will change.