Oceanographic Research in Relation to Fisheries Research

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OCEANOGRAPHIC RESEARCH IN RELATION TO FISHERIES RESEARCH

by

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ABSTRACT

Sinclair, M., C.M. Hawkins, R. Mahon, T.L. Marshall, R.N. O'Boyle, J.F. Uthe, and A. White. 1986. Oceanographic research in relation to fisheries research. Can. Tech. Rep. Fish. Aquat. Sci. 1443: v + 21 p.

A task group of the Fisheries Research Branch, Scotia-Fundy Region, considered the oceanographic research requirements for fisheries management research relating to stock assessment and habitat protection activities. The important questions in fisheries research were identified, and subsequently the requirements for oceanographic research were evaluated. Recommendations include: 1) a strong research commitment be directed toward describing the oceanographic features of the commercial fishing areas off the east coast of Canada (in particular on biological oceanographic properties - phytoplankton, zooplankton, and benthos); 2) emphasis be directed toward the inter-annual time scale of oceanographic phenomena (which is particularly lacking in the present biological oceanographic research programs); 3) strong oceanographic research support be continued for the "process-oriented" studies directed toward an understanding of recruitment variability of commercially important species; and 4) oceanographic research place some emphasis on the definition of "natural" fish production management units to the degree that they exist (i.e. to help define geographic scale of fish communities).

RÉSUMÉ

Sinclair, M., C.M. Hawkins, R. Mahon, T.L. Marshall, R.N. O'Boyle, J.F. Uthe, and A. White. 1986. Oceanographic research in relation to fisheries research. Can. Tech. Rep. Fish. Aquat. Sci. 1443: v + 21 p.

Un groupe d'étude de la Direction de la recherche sur les pêches, région de Scotia-Fundy, s'est penché sur les besoins de travaux de recherche océanographique sur les évaluations de stocks et les activités de protection de l'habitat. On a d'abord cerné les questions importantes propres à la recherche sur les pêches pour ensuite évaluer les besoins sur le plan de la recherche océanographique. Les recommandations comprennent les mesures suivantes: 1) qu'on s'engage fermement à orienter la recherche vers la définition des caractéristiques océanographiques des zones de pêche commerciale au large de la côte est du Canada (plus particulièrement sur les propriétés océanographiques biologiques - phytoplancton, zooplancton, et benthos); 2) qu'on mette l'accent sur l'échelle de temps interannuelle des phénomènes océanographiques (il s'agit d'une grande lacune dans les programmes actuels de recherche

océanographique biologique); 3) que le soutien à la recherche biologique soit maintenue pour les études détaillées visant à expliquer la variabilité du recrutement d'espèces commerciales importantes; et 4) que la recherche océanographique se penche sur la définition d'unités de gestion de la production de poissons "naturels," dans la mesure où elles existent (c.-à-d. aider à définir l'échelle géographique de populations de poisson).

INTRODUCTION

A task group of the Fisheries Research Branch, Scotia-Fundy Region, was formed in 1983 to define and describe what the realistic needs and expectations are or should be for fisheries research in the realm of physical and biological oceanography. This task was divided into two components. First, the scope and important research questions within fisheries research were defined; and secondly, the oceanographic research activities in support of the fisheries research questions were described briefly.

DEFINITION OF MAJOR RESEARCH QUESTIONS IN "FISHERIES RESEARCH"

Before the needs for oceanographic research in support of "fisheries research" were defined, it was deemed necessary to identify the major research questions within the field of fisheries research as conducted by the Atlantic Fisheries Service of the Department of Fisheries and Oceans. Fortunately there is an impressive amount of documentation currently available (such as the Multi-Year Operations Plans by Region, the report of the Atlantic Fish Habitat Task Group, and the Fisheries Research Branch Scotia-Fundy Region Blue Book) fully describing the scope of fisheries research in the present context. In the attempt to distill this information, and to obtain the critical research questions, there is a danger of reducing the substance to the degree that the product becomes trite, or at best bland. Secondly, the selection of what is considered to be state of the art, in fisheries research, is to a certain degree subjective depending on the particular disciplinary matrix of the working group.

Accepting these constraints, the two questions asked in this section are:

1. What is the scope of fisheries research?

2. What are the fundamental research questions within the defined scope?

For the second question some thought was given to the difference between research done in support of state-of-the-art fisheries and habitat management in contrast to that in support of improved or future management approaches. It is felt that if the scope and the research questions were well defined the associated oceanographic requirements should be readily identifiable.

The scope of fisheries research within the Atlantic Fisheries Service includes:

1. Fisheries management-related research. Such research is directed toward understanding fish distributions, migrations, stock delineation, etc., and deals with numbers and weight of commercially exploited populations. The core discipline is population dynamics. The types of questions asked are: What are the populations, or are there indeed separate self-sustaining populations within the overall distribution of the species? How large are the populations? How much fish or how many invertebrates can be taken optimally from the population annually and still have a self-sustaining, relatively stable population? These questions indicate the scope of fisheries management-related research (defined here in a somewhat narrow sense).

2. Habitat-related research.

   > "Fish habitat research is defined as science-based undertakings which provide the background necessary for habitat conservation, improvement, and protection. Included within this definition are not only the more clearly identified research activities (i.e. environmental assessment, toxicology, inventory monitoring, etc.) which support habitat intervention <u>per se</u> but as well, broader areas of fisheries and environmental science such as ecology, limnology, oceanography, population biology, etc."[1]

   Thus, if the above broad definition of habitat research is used, and it frequently is, almost all scientific disciplines can be included. For the purposes of this report, a narrower scope has been adopted (research directly related to the assessment of habitat). In this narrow view habitat research is directed to that necessary to conserve, restore, and develop fish habitats with particular emphasis on impacts on populations of commercial interest. It deals with the forecasting of fish habitat changes which are caused by: i) forestry, agriculture, and fisheries operations; ii) energy development; iii) mineral industries; iv) chemical hazards; v) public and private works; and vi) natural processes (see report of the Atlantic Fish Habitat Task Group for detailed a brief on the scope of habitat research).

3. Aquaculture-related research. Research in this category deals with the controlled production of commercially important species and includes investigations in the fields

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[1]Fish Habitat Task Force Report - Research (1983), internal Department of Fisheries and Oceans report.

of nutrition, physiology, genetics, environmental requirements, growth, and control of disease among others. In the context of oceanographic research needs, the rapid development of the salmonid cage culture and molluscan culture requires better ocean environment information at the more local/coastal level. For example, any improvement in our understanding of the process governing fluctuations in temperature and circulation in areas of promise for aquaculture developments should be encouraged. Notwithstanding the above, oceanographic research in support of aquaculture-related programs is of a different nature compared with those for fisheries management and habitat-related research. In order to limit the discussion of the report, it has been decided not to consider the specific requirements for aquaculture developments further in this document.

For the purpose of this report, then, the questions of fisheries management and habitat research defined in a narrower-than-usual context are discussed. What then are the fundamental research questions within the defined scope? The fisheries management research questions are addressed first.

FISHERIES MANAGEMENT-RELATED RESEARCH

The steps in the stock assessment process are a useful initial guide to the key research questions, and they provide a logical structure for the presentation (the temporal/spatial scales of the research questions are indicated by an asterisk).

1. Step 1 is the definition of the management units themselves. The research question is, as briefly stated above: Within the overall distribution of the species are there smaller population units that are in a biological sense reasonable to manage separately? This question deals with the population structure of the species including the life history and annual migrations. It includes the diverse research activities within the Atlantic Zone on stock discrimination and tagging. An important feature to note with respect to
* the subsequent section on oceanographic needs is the spatial scale of importance to the definition of the population structure (10^5-10^6 m).

2. Step 2 is the annual description of the resource using both fishery-dependent and fishery-independent data sources. The latter source, which involves research programs, includes trawl surveys, acoustic surveys, and larval surveys. The research question here deals with the spatial distribution of the phase of the life history being surveyed (i.e. how are the organisms distributed, and how are the abundances best estimated?). This broad question embraces much of the

resource survey activity. It involves both the practical aspects of sampling methodology as well as the more fundamental ecological question of the control of spatial distribution of animal numbers. The spatial scale of interest here, at least in coming to grips with the variance of the abundance estimates, as well as their accuracy, is smaller (10^2-10^3 m).

3. Step 3 is the estimation of numbers of fish or invertebrates at each age in the management unit using Sequential Population Analysis (SPA). There are several important research questions related to this step. Is a single-species SPA a valid approach to estimating population numbers since it (as presently applied) ignores feeding interactions between species in using the assumption of constant natural mortality both between ages and between years? The research questions then are: How important is predation by other commercially exploited species as well as non-commercial species on the target species particularly at the younger ages, and how important is disease in generating variable natural mortality in a "wild" fished population? A second, and somewhat related, problem at this step involves the forecasting of recruitment and its use in fine tuning the critical age groups in the SPA (the pre- and partially recruited ages). The biological questions involve understanding the time in the life history at which the relative size of the year class is fixed, as well as the geographic area in which the juveniles recruiting to the management unit are distributed. For accurate fine tuning of the SPA such information is needed. In other words, how is natural mortality distributed throughout the life history; and can the inter-annual variability in this mortality be "forecasted" if not predicted (i.e. by an index of relative strength of recruiting year classes)? It is important to note again the scale, in this case temporal, of the critical events. In north temperate waters at least, recruitment is an annual event and the exploited populations are structured by age. It is the inter-annual time scale that is important in this component of fisheries management research (i.e. estimation of population numbers at age). It is to be noted that recruitment variability is addressed twice (here and under Step 5). The emphasis here is on identifying at what age the year-class size is established and how its relative size can be forecasted. The emphasis under Step 5 is on understanding what causes recruitment variability.

4. Step 4 is the estimation of the optimal fishing mortality that should be applied to the exploited "population" in the management unit. At present the analytical yield model (or yield-per-recruit model) is used to generate the appropriate fishing mortality. There are two classes of research

questions associated with this step. The first class assumes that the model is a useful one and the research is directed toward the required population parameters for the model (growth, fecundity, natural mortality). The second research thrust questions the underlying assumptions of the model (its steady-state assumptions, its lack of inclusion of species interactions, its decoupling from recruitment) and searches for improved approaches.

5. Step 5 involves the application of Step 4 (fishing mortality) to Step 3 (abundance at age) to generate recommended Total Allowable Catches (TAC's). The research question here is fundamental: Does the single-species analytical yield model (Steps 1 to 5), which in theory should prevent "growth" overfishing, ensure that "recruitment" overfishing does not occur? [Growth and recruitment overfishing are used in the sense defined by Cushing (1975).] Secondly, are the combined single-species TAC's for a geographic area a meaningful or optimal yield for the species complex as a whole given that species and fisheries interactions are ignored in the process? The temporal/spatial oceanographic scales of interest for these two fundamental questions again need emphasis in the context of this report. Present approaches to this problem stress the importance of the small scale in coming to grips with the recruitment variability question
* (and presumably the stock/recruitment relationship) (10^{-1} to 10^{2} m and days). The question of the definition of geographic areas within which are found meaningful interactive exploited species complexes is studied on a larger scale (perhaps 10^{5} m).

The research questions identified here for fisheries management research are summarized in Table 1.

FISH HABITAT-RELATED RESEARCH

The habitat research questions are presented in four categories related largely to impacts of man's activities on fish populations: description of the respective habitats, impacts of human activities on specific habitats, development of habitat quality indicators, and monitoring of chronically disturbed habitats. The summary of research questions is restricted to those activities that are marine, in keeping with the aim of this report (to define the <u>oceanographic</u> research needs for fish habitat research).

1. Description of fish habitats. In order to describe or predict effects of various future human activities on commercial species or communities or organisms the relatively undisturbed condition has to be documented. To this end,

several types of "baseline" studies can be identified. These include: i) studies of the ecosystem or community structure and linkages between biotic and abiotic components of fish habitat; and ii) studies of contaminant levels in selected target commercial species in different habitats as well as studies of these contaminants in the organism's environment and the fluxes. The research questions are then: What is the community structure in various "fish habitats"? What are the ambient concentrations of naturally occurring or recently introduced chemical pollutants?

2. Impacts of human activities on fish habitat. Studies are undertaken either to predict the impact of a major modification of fish habitat prior to the implementation or to monitor the impact as the modification occurs. Examples include the investigation of the impact of eutrophic wastes (such as pulp mill effluents) on receiving waters, the impact of modification of seasonal patterns of freshwater runoff on the marine environment (hydroelectric developments), impact of modification of tidal regimes (Fundy Tidal Project), and impact of dredging in the coastal zones (Miramichi estuary). In this category of activities each project has its specific research questions which cannot be usefully generalized, and they are frequently site specific rather than process oriented.

3. Development of habitat quality indicators. In order to have "early warnings" of habitat deterioration, research is directed to sublethal effects of various contaminants. The research question here is: What are the sublethal effects of a particular contaminant on the biology of a target indicator species?

4. Monitoring of disturbed habitats. In particular health hazard situations where commercially exploited species are severely contaminated, such as in the heavy metal contamination of lobsters in a northeast New Brunswick area, continuous monitoring of the fish habitat is required.

The marine fish habitat research areas are summarized in Table 2.

What now can be gleaned from this summary of research questions in "fisheries research"? There are some features that are noteworthy: the temporal-spatial scale, and the site specificity. The oceanographic needs are identified in the following section.

REQUIREMENTS FOR OCEANOGRAPHIC RESEARCH IN RELATION TO THE "FISHERIES RESEARCH" QUESTIONS DEFINED IN THE PREVIOUS SECTION

The requirements for fisheries management research are addressed first, following the list in Table 1. It has been stated above that the time and space scales of interest to fisheries research questions are broad, with several of the important phenomena occurring at the upper end of the range (inter-annual events and hundreds of kilometers). A second general point that can be made is that the oceanographic knowledge required is to a large degree site specific descriptive oceanography rather than process oriented. These two points (scale and site specificity) are brought out further below. Some of the oceanographic knowledge required may be, in practical terms, difficult to acquire with present techniques and human resources. At this stage this fact should not stop us from identifying the need.

DISCUSSION OF QUESTIONS LISTED IN TABLE 1

Question 1 - Population Structure for Definition of Management Units

The population structure for most species is defined over large areas, and the seasonal migrations can cover hundreds or thousands of kilometers. As background information, in support of fish population structure studies, descriptive physical and biological oceanography of the continental shelves of the northwest Atlantic are required on this larger scale. For example,

- Description of the residual circulation, and the seasonal differences, within the Gulf of St. Lawrence and over the continental shelves from the Labrador Shelf to the Gulf of Maine (the ongoing Labrador Current and southwest Nova Scotia studies and the long-term temperature-monitoring program by the Atlantic Oceanography Laboratory (AOL) (Bedford Institute of Oceanography, Dartmouth, N.S.) are examples of the type of descriptive studies that are needed).

- Description of phytoplankton seasonal production cycles in the Gulf of St. Lawrence and the offshore shelf areas. At present the seasonal phytoplankton production features are not understood or even described for any offshore area; certain inshore areas (Bedford Basin, St. Margaret's Bay, St. George's Bay, and the St. Lawrence Estuary) are well studied. It is felt that there are features of scale itself that may contribute to phytoplankton dynamics such that the process studies and distributions described in coastal embayments are not necessarily appropriate to the offshore areas.

- Description of zooplankton seasonal production cycles in the Gulf of St. Lawrence and the offshore shelf areas. The Scotian Shelf Ichthyoplankton Program (SSIP) results indicate differences between areas of the Scotian Shelf in both the timing of events as well as in species composition. The sampling design, however, was not adequate to describe the zooplankton seasonal dynamics. The lack of knowledge on zooplankton biology in the eastern Canadian waters was noted in a report commissioned by the Atlantic Directors (Bugden *et al.* 1982).

- Description of the distribution of the benthos in the Gulf of St. Lawrence and the offshore shelf areas. In the preparation of material for resolution of the Gulf of Maine boundary dispute it was particularly evident that essentially nothing is known about the distribution and production of the benthos on the Scotian Shelf. This situation is paralleled in the Gulf of St. Lawrence and the other shelf areas off Newfoundland and Labrador to the northeast.

In sum, to understand why species range so broadly and divide into diverse self-sustaining populations characterized by specific life-history and seasonal migrations, it is necessary to have a better knowledge of the geographic and seasonal oceanographic features of the specific shelf areas in question (i.e. descriptive oceanography at appropriate time and space scales).

Question 2 - Small-Scale Distributions for Different Life-History Stages

Variances in abundance estimates of commercial species are large, indicating that their distributions are very patchy. We are perhaps not yet at the stage of asking specific oceanographic research questions to better understand what controls the small-scale distributions of exploited species.

Question 3 - Estimation of Importance of Predation

No specific oceanographic requirements at this time.

Question 4 - Understanding the Time at Which the Year-Class Size is Established

Studies on the distribution of mortality through the life history of commercially exploited species does not in itself require oceanographic research. However, an understanding of the inter-annual variability in the oceanographic environment is essential to making progress in our ability to predict or forecast variability in year-class strengths. This is addressed further under Question 7. Until there is a better understanding of the generation of recruitment variability for commercially important species (which is a major area of research in itself) it is difficult to be specific about what features of the inter-annual variability should be studied. It would seem here that a "process-oriented" approach to the inter-annual time scale of oceanographic phenomena is to be preferred. An understanding, or even good descriptions, of inter-annual variability in the oceanographic features of the shelf areas would be important in understanding (predicting ?) differences in migration patterns of commercially important species such as mackerel and squid. In contrast to the oceanographic research identified under Question 1, simple descriptions of the oceanographic variability are not sufficient. It is of interest to note that it was recognized in the early years of the International Council on the Exploration of the Sea (ICES) that an understanding of fisheries yield variability in the northeast Atlantic was dependent on understanding large-scale oceanographic phenomena on an inter-annual time scale. At the 1922 meeting, for example, it was,

> "considered that a continuous record of the intensity of the current at the source of the Gulf Stream over a period of years would be of great practical importance to the fisheries [of the northeast Atlantic]."

Given that it is unlikely that universities can afford studies of this longer yet critical time scale there is a need for a sustained commitment by the Department of Fisheries and Oceans to address such problems.

Question 5 - Estimation of Population Parameters

No oceanographic requirements.

Question 6 - Development of New Fisheries Management Models

No oceanographic requirements (this is not to say that oceanographers may not want to do research on fisheries management models).

Question 7 - Understanding Recruitment Variability and Stock/ Recruitment Relationships

In 1914, J. Hjort in his classic paper did several things. First, he convincingly demonstrated that the population (or stock) is the unit of study, not the species, when one is addressing the problem of explaining inter-annual variability in fish catches. Second, he summarized the available growth and year-class information on cod, haddock, and herring in the northeast Atlantic and concluded that the species have relatively long lives (up to 20 yr or more), the populations are structured by age, and the inter-annual variability in catches is to a large degree defined by variability in the strength of year classes. Third, he generalized that the relative strengths of the year classes are fixed or established within the first couple of years of the life span. Fourth, he identified two general classes of phenomena that might be important in generating the inter-annual variability in survival of the cohorts (a matching of the spawning event to appropriate plankton events, both events having characteristic variances; and inter-annual differences in advection of eggs and larvae away from the appropriate area). In his 1926 paper it is of interest that he comes down slightly in favor of the physics (advection differences) over food ("critical period"). Finally (in the 1914 classic) Hjort predicts that nothing of practical fisheries management use (presumably in the short term) will come from studying the recruitment variability problem. Seven decades after his magnificent contribution, it is clear that he had remarkable foresight. Many details have been added to his synthesis, but there appear to be few significant increases in understanding. The accumulated research has not contributed significantly to fisheries management.

This preamble to the Question 7 oceanographic needs has been included not to downgrade either the importance of this research area or the quality of research that has been undertaken in addressing the research problem, but rather to indicate the complexity of the problem. Understanding recruitment variability is without doubt the number one problem in fisheries management research, and one which requires extensive oceanographic support. The recent International Recruitment Project (IREP) report to the International Oceanographic Commission (IOC) has, for example, fully documented the state of the art and identified in detail what are considered the most fruitful directions for oceanographic research. Our Task Group can do no more than to support the critical importance of oceanographic research focussed toward this general topic.

The Task Group does feel, however, that progress in Question 1 may be critical to making any significant advances in Question 7. Understanding why species are broken up into particular populations having a wide range of mean sizes (ranging over several orders of magnitude for some species) may be crucial to understanding what controls the variances around the mean (generally less than an order of magnitude). Thus oceanographic research should, in our view, be focussed on both halves of the stock and recruitment problem. All of the oceanographic "effort" should not be put into one direction (micro-structure process-oriented studies).

Question 8 - Definition of Meaningful Species Complexes

This research question is particularly fruitful for meaningful research cooperation between fisheries biology and oceanography. The descriptive oceanography on the circulation, phytoplankton, zooplankton, and benthos of the Gulf of St. Lawrence and offshore shelf areas mentioned in Question 1 above would provide a very useful framework within which to approach community structure and function.

There are two logical components to this research area. First, are there species associations with geographic coherence that merit some form of multi-species management? These fish associations have to be identified, and the coupling with the physical, plankton, and benthos features investigated. Second, after the "associations" have been identified in their oceanographic context, the trophic-dynamic aspects of the community merit study. The links between fish production and the lower trophic levels, and the physical oceanography, are of interest in this second component.

DISCUSSION OF FISH HABITAT RESEARCH QUESTIONS LISTED IN TABLE 2

Question 1 - Description and Understanding of Community Structure and Function

The ultimate goal of oceanographic research related to habitat assessment is to provide information by which fisheries and fish habitat biologists can describe systems and processes precisely leading to commercial fish production and hence predict the likely effects of natural and man-made perturbations. We need to identify and/or predict changes in community structure and function on impacts either by man-induced factors (i.e. overfishing, pollution, physical disruptions, etc.) or by natural processes (i.e. short- and long-term variations in marine climate and in biological and chemical oceanographic conditions). With this knowledge at hand, researchers and managers can make prudent decisions regarding the future exploitation of important community components (stocks) and the consequent repercussions expected for the community and/or ecosystem.

It is well recognized that we know little about the structure and function of communities on our fishing banks and within the near-shore coastal zone. What is needed are well-integrated multi-disciplinary research groups with a long-term commitment to the primary goal in fish habitat research: to determine the impacts of man-induced changes on the commercially important species in the marine environment. A precedent has been set in part as illustrated by various group involvements in the Bay of Fundy Tidal Power Ecosystem Study. Here a long-term commitment was met (the study group was established ca. 1978 and is ongoing) with the modelling of the system now in progress. A similar program has been established to study one of the major fishing banks off the Nova Scotia coast (Fisheries Ecology Program). Such baseline studies should lead to a more predictive capacity in relation to impact statements.

Question 2 - Description of Concentrations of Contaminants and Their Fluxes

No specific oceanographic requirements at this time. (To the degree that pathways and fates of contaminants are to be understood, however, there are oceanographic requirements. A somewhat narrow view of this question is taken here.)

Question 3 - Site-Specific Studies on the Impacts of Human Activity

Since many of the impacts occur in the coastal zone, there is a need for research on the circulation and mixing in the specific near-shore sites where the impact is to occur.

Question 4 - Development of "Early-Warning" Indicators

No specific oceanographic requirements at this time.

CONCLUSIONS AND RECOMMENDATIONS

Two features of fisheries research have been noted; first, several of the important research questions in fisheries have to be studied at relatively large time and space scales (inter-annual events and hundreds of kilometers); and secondly, much of the research is site specific. These characteristics in themselves provide a focus for defining supporting oceanographic research. The important research questions in fisheries management and fish habitat research are listed respectively in Tables 1 and 2, together with summaries of the respective oceanographic thrusts required. Before the recommendations are made a general comment on the degree of coupling between fisheries and oceanographic research may be useful. In the planning and direction of oceanographic research too tight a linkage may not be optimal.

There are several important areas in fisheries research where there is not a clear research direction that one can feel with confidence will lead to an increase in our understanding. The general questions concerning inter-annual variability in year-class strengths or migration patterns are good examples.

Rather than focus the oceanographic research directly on specific fisheries problems at this time and space scale (for example on cod year-class strength variability on Grand Bank) it may be preferable to make a research commitment to this scale of phenomena in general terms, giving the oceanographers the freedom to decide on which directions are likely to lead to significantly increased understanding. There are other research areas, however, where a tight coupling is to be recommended (Table 1, Questions 7 and 8, for example). The fisheries management research recommendations are:

1. It is recommended that a strong research commitment be directed toward describing the oceanographic features of the commercial fishing areas off the east coast of Canada. A considerable amount of research on the physical oceanography of the east coast continental shelf has already been conducted. Broader geographic coverage and an emphasis on the inter-annual time scale of variability is is of course desirable. In contrast very little descriptive work is being done, or has been done, on the biological oceanography (phytoplankton, zooplankton, and benthos) of the relevant continental shelf. Do offshore banks, for example, have different biological oceanographic properties than the contiguous basin areas? The fisheries biology work is hindered in its development by a lack of understanding of the biological oceanography. Tight coupling between fisheries and oceanography would go far toward overcoming these problems.

2. It is recommended that a strong commitment be directed toward the study of the inter-annual time scale of oceanographic phenomena. This is the critical scale of interest to several important fisheries management questions. Some research at this time scale is being conducted on the physical oceanography, but essentially nothing is being done on the biological oceanographic features. This time scale is being seriously addressed by the fisheries biologists particularly through the groundfish survey programs. Because of the poor understanding of this time scale of oceanographic phenomena tight coupling of fisheries and oceanographic research is considered less important than the commitment itself to tackling the general problem. The fisheries biology and oceanography can come together at an appropriate time as understanding increases. The question of long-term monitoring of oceanographic properties in relation to fisheries research was not considered in any depth by the working group. Some members felt that until increased understanding of what generates inter-annual variability in oceanographic properties is gained it is premature to establish an elaborate monitoring network. Others felt that

long-term monitoring of oceanographic properties should have a high priority. A concensus was not reached.

3. It is recommended that the "process-oriented" studies directed toward an understanding of recruitment variability of commercially exploited species receive strong support. The task group did not deal with this research area in any detail since the IREP report to IOC has recently fully reviewed this subject. This research area, which is focussed on the early life-history stages (egg, larval, and juvenile), is where the two disciplines of fisheries biology and oceanography directly overlap. Clearly, tight coupling of research in this subject area is essential.

4. It is recommended that oceanographic research place emphasis on the definition of "natural" fish production management units, to the degree that they exist. The present trend away from single-species management (which ignores species interactions) toward management by geographic area is taking place without consideration of what could be called the "oceanographic forcing" of fish species associations. If there are meaningful fish associations or communities they no doubt exist in relation to oceanographic features and processes.

The fish habitat research recommendations are listed below.

1. It is recommended that the emphasis be continued on biological oceanographic studies directed toward an increased understanding of community structure and function. This increase in fundamental understanding of marine communities will enhance our ability to predict the impacts of man's activities on various fish habitats. Tight coupling with fish habitat activities is not required since it is more important that fundamental understanding is acquired rather than site-specific descriptions at this time.

2. It is recommended that there be an increased emphasis on physical oceanographic research on the circulation and mixing processes in the sensitive coastal zone environment.

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Table 1

Important questions in fisheries management research.	Oceanographic research required to support fisheries management research.
1. Population structure of the commercially exploited species, including understanding of life-history distributions and annual migrations (to aid in definition of management units).	1. Descriptive studies on the circulation, phytoplankton, zooplankton, and benthos of the Gulf of St. Lawrence, the Bay of Fundy, and the offshore shelf areas.
2. Small-scale characteristics of the spatial distribution of different phases of the life history of the commercially exploited species (in relation to deriving estimates of abundance for fine tuning SPA).	2. No research specified.
3. Estimation of the importance of predation, particularly on juveniles (including post-smolt salmon), in the calculation of natural mortality (to be used in SPA).	3. No research specified.
4. Understanding of the time in the life history at which the relative size of the year class is defined (in order to monitor recruitment and fine tune SPA).	4. "Process-oriented" approach to the inter-annual time scale of oceanographic phenomena.
5. Estimation of population parameters (growth, fecundity, natural mortality) required for fisheries yield models (to generate fishing mortalities in relation to management objectives).	5. No research specified.

.../Contd. .../Contd.

Table 1 Contd...

Important questions in fisheries management research.	Oceanographic research required to support fisheries management research.
6. Development of new fisheries management models that have less-demanding assumptions (to develop new management approaches).	6. No research specified.
7. Understanding of the mechanisms controlling recruitment variability and the stock/recruitment relationships (to evaluate the coupling of "growth-overfishing" and "recruitment overfishing" models).	7. Studies on the causes of recruitment variability of commercially exploited species.
8. Definition of meaningful species complexes or associations in their geographic context for multi-species management.	8a. Identification of oceanographic forcing in the formation of "fish associations." b. Studies of community structure and function of the identified "fish associations."

Table 2

Important questions in fish habitat research.	Oceanographic research required to support fish habitat research.
1. Description and understanding of community structure and function in various habitats (fundamental studies).	1. Oceanographic research (biological, chemical, and physical) directed toward an understanding of community structure and function.
2. Description of concentrations of contaminants and their fluxes in components of various habitats (baseline studies).	2. No research specified (note that a narrow scope has been taken).
3. Site-specific studies of impact of human activity (x) on habitat (y) (impact studies), including relationships with commercial fisheries.	3. Physical oceanographic studies on circulation and mixing of selected sensitive coastal zone or offshore areas.
4. Development of "early-warning" indicators of habitat deterioration by analysis of sublethal effects.	4. No research specified.