Excellence scientifique • Protection et conservation des ressources • Bénéfices aux Canadiens
Scientific Excellence • Resource Protection & Conservation • Benefits for Canadians

Compte Rendu d'un Atelier: Études de l'écosystème marin du détroit d'Hudson

Proceedings of a Workshop: Marine Ecosystem studies in Hudson Strait

Novembre 9 - 10 November, 1989
Montréal, Québec

Éditeur / Editor

J.A. Percy

Station de biologie arctique / Arctic Biological Station
Institut Maurice Lamontagne
Ministère des Pêches et des Océans
555 boul. St-Pierre
Ste-Anne-de-Bellevue, Québec H9X 3R4

Novembre / November 1990

Rapport technique canadien des sciences halieutiques et aquatiques No. 1770

Canadian Technical Report of Fisheries and Aquatic Sciences No. 1770

Pêches et Océans
Fisheries and Oceans

Canada

Rapport technique canadien des sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annual des publications scientifiques et techniques du Ministère.

Les numéros 1 à 456 de cette série ont été publiés à titre de rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Technical Report of Fisheries and Aquatic Sciences

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1–456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457–714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715–924 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport technique canadien des sciences halieutiques et aquatiques No. 1770

Canadian Technical Report of Fisheries and Aquatic Sciences No. 1770

Novembre/November 1990

Compte Rendu d'un Atelier: Études de l'écosystème marin du détroit d'Hudson

Proceedings of a Workshop: Marine Ecosystem Studies in Hudson Strait

November 9 - 10 Novembre, 1989
Montréal, Québec

Editeur/Editor

J.A. Percy

Station de biologie arctique/Arctic Biological Station
Institut Maurice Lamontagne
Ministère des Pêches et des Océans
555 boul. St-Pierre
Ste-Anne-de-Bellevue, Québec H9X 3R4

No. de cat. Fs 97-6/1770
ISSN 0706-6457

Cat. No. Fs 97-6/1770
ISSN 0706-6457

On devra référer comme suit à cette publication:

Percy, J.A. (éd.). 1990. Compte rendu d'un atelier: Etudes de l'écosystème marin du detroit d'Hudson. 9-10 Novembre 1989, Montréal (Québec). Rapp. tech. can. sci. halieut. aquat. 1770: xiv + 175 p.

Correct citation for this publication:

Percy, J.A. (ed.). 1990. Proceedings of a workshop: Marine Ecosystem Studies in Hudson Strait. November 9-10, 1989, Montréal, Québec. Can. Tech. Rep. Fish. Aquat. Sci. 1770: xiv + 175 p.

TABLE DES MATIÈRES / TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Percy, J.A. (ed.). 1990. Proceedings of a workshop: Marine Ecosystem Studies in Hudson Strait. November 9-10, 1989, Montréal, Québec. Can. Tech. Rep. Fish. Aquat. Sci. 1770: xiv + 175 p.

This report presents the results of a workshop on the marine ecosystem of Hudson Strait sponsored by the Quebec region of DFO. The objectives of this workshop were to review the information presently available about the structure and functioning of the Hudson Strait marine ecosystem, pinpoint significant gaps in our knowledge and identify promising directions for future research. The report contains comprehensive reviews of the environment and biota of the region as well as the abstracts of papers dealing with specific research topics that were presented at the workshop. Also included are the summary reports of several working groups that pinpoint existing data gaps and identify potential threats to northern Québec marine ecosystems that need to be evaluated and monitored. An extensive list of marine studies that could feasibly be conducted in the Hudson Strait region is presented. The recommendations of the Steering Committee regarding the further development of a program of Marine Ecosystem Studies in Hudson Strait are also included.

RÉSUMÉ

Percy, J.A. (éd.). 1990. Compte rendu d'un atelier: Études de l'écosystème marin du détroit d'Hudson. 9-10 Novembre 1989, Montréal (Québec). Rapp. tech. can. sci. halieut. 1770: xiv + 175 p.

On présente les résultats d'un atelier sur l'écosystème marin du détroit d'Hudson qui a été organisé par le bureau de la région du Québec du MPO. Les objectifs de l'atelier étaient d'étudier toute l'information dont nous disposons actuellement sur la structure et le fonctionnement de l'écosystème marin dans le détroit d'Hudson, de cerner les principales lacunes dans nos connaissances et de déterminer les orientations prometteuses de la recherche future. Le rapport contient des études exhaustives de l'environnement et du biote de la région ainsi que des résumés des exposés sur des sujets de recherche précis qui ont été présentés lors de l'atelier. En outre, on y trouve des résumés des rapports soumis par plusieurs groupes de travail qui font état des lacunes existantes en matière de données ainsi que des dangers qui menacent les écosystèmes marins du nord du Québec et qu'il faudrait évaluer et surveiller. On donne également une liste complète des études de l'écosystème marin que l'on pourrait mener dans la région du détroit d'Hudson. Enfin, on présente les recommandations du Comité directeur concernant l'expansion d'un programme d'études de l'écosystème marin dans le détroit d'Hudson.

RÉSUMÉ D'ORIENTATION

Le détroit d'Hudson est une longue vallée submergée qui se trouve au nord du 60° parallèle et qui sépare l'île de Baffin, dans les Territoires du Nord-Ouest, de la péninsule d'Ungava, dans le nord du Québec. Il est orienté vers le nord-ouest à partir de son entrée est et relie la mer du Labrador et le détroit de Davis au bassin Foxe et à la baie d'Hudson dans l'ouest. Sa longueur est d'environ 750 km et sa largeur moyenne d'environ 125 km, avec une largeur minimale de 70 km à son entrée est et une largeur maximale de 240 km à proximité de la baie Déception à l'ouest. La baie d'Ungava est une grande nappe d'eau en forme de U qui se trouve immédiatement à l'entrée est du détroit, et elle s'étend directement vers le sud. Elle a une largeur de 200 km à l'embouchure et une profondeur de 250 km vers le sud.

Les collectivités autochtones qui vivent sur le bord du détroit d'Hudson et de la baie d'Ungava dépendent depuis longtemps du milieu marin pour la majeure partie de leur nourriture. Depuis toujours, plusieurs espèces de mammifères marins et de poissons anadromes constituent leur principales prises. Depuis environ 1980, ces collectivités s'intéressent de plus en plus à d'autres espèces marines qui présentent certaines possibilités de récoltes de petite envergure. Cet intérêt renouvelé pour les ressources marines arrive à un moment d'appréhension grandissante au sujet des impacts possibles de diverses menaces environnementales sur l'écosystème marin. On se préoccupe principalement de l'aménagement hydroélectrique continuel des principales rivières qui modifie le transport des eaux douces, des matières organiques terrigènes et du mercure dans le milieu marin dans le nord québécois. On a supposé que les variations au niveau de l'écoulement des eaux douces influençaient considérablement les processus de brassage dans le détroit d'Hudson et que ce dernier influait sur la production biologique, non seulement dans le détroit même mais également sur les fonds de pêche productifs du plateau continental du Labrador. On s'inquiète également de plus en plus de la possibilité que le réchauffement atmosphérique attribué à l'effet de serre puisse entraîner d'importantes modifications au niveau des écosystèmes marins, principalement dans ces régions septentrionales. La détection de pesticides, de BPC, de cadmium et d'une vaste gamme d'autres contaminants industriels dans les habitats et la faune du Nord constitue une raison de plus pour s'inquiéter.

La gestion, la conservation et la mise en valeur des ressources marines de la région sont sujettes à des revendications territoriales en suspens ainsi qu'à des accords définissant les droits et les obligations des parties en cause. Les accords cherchent principalement à assurer la protection des espèces ressources et de leurs milieux physiques et biologiques malgré les activités de développement dans la région. Ces priorités en matière de gestion et de conservation dépendent de la recherche scientifique permanente pour fournir des informations sur le biote marin et ses habitats, et pour mieux faire comprendre les rapports qui existent entre les espèces-clés qui constituent des chaînes trophiques marines. La recherche et le développement en matière de pêche et la recherche connexe en océanographie physique, chimique et biologique de ces eaux du nord du Québec ont donc été considérés comme d'importantes priorités par le bureau de la région du Québec du MPO et ses clients. Jusqu'à présent, il y a eu très peu de recherche sur le biote, et nous connaissons très peu l'écologie de

base des populations marines, et presque rien des processus de l'écosystème qui les régissent.

Il faudra certainement déployer des efforts de recherche considérables et soutenus pour augmenter sensiblement notre compréhension de son écologie. **Il est donc proposé d'entreprendre un programme multidisciplinaire complet d'Études de l'écosystème marin dans le détroit d'Hudson (EEMDH) par la région du Québec du MPO.** En guise de première étape pour l'élaboration d'un tel programme, les chercheurs en sciences marines arctiques de tout le Canada se sont réunis à Montréal en novembre 1989 pour un atelier d'étude sur l'écosystème marin du détroit d'Hudson. Les objectifs de cet atelier étaient d'étudier toute l'information dont nous disposons actuellement sur la structure et le fonctionnement de l'écosystème marin dans le détroit d'Hudson, de cerner les grandes lacunes de nos connaissances et d'identifier les orientations prometteuses de recherche future. L'information disponible a été présentée dans une série de communications faites dans chacun des domaines suivants:

- océanographie physique et chimique
- phytoplancton, zooplancton et biote glaciaire
- poissons et invertébrés benthiques
- oiseaux marins
- mammifères marins
- gestion des ressources

Les participants ont ensuite été divisés en groupes de travail pour traiter des besoins de recherche pour les quatre thèmes généraux suivants:

- production planctonique et glaciaire
- poissons et invertébrés commerciaux
- oiseaux et mammifères marins
- gestion des ressources et incidences environnementales

Les groupes de travail ont identifié les lacunes actuelles en matière de données et les menaces possibles pour les écosystèmes marins du Nord qui doivent être évalués et surveillés. On a dressé une liste exhaustive des études possibles dans une variété de disciplines.

Un comité directeur a revu la version préliminaire du compte rendu de l'atelier et fait des recommandations relativement à l'élaboration d'un programme d'études de l'écosystème marin dans le détroit d'Hudson. **Le comité a conclu qu'un tel programme de recherche est justifié, opportun et faisable et qu'il devrait être élaboré davantage et mis en application le plus tôt possible.** En ce qui a trait au potentiel des ressources de la région et aux nombreuses menaces environnementales pour l'écosystème, il y a un besoin net d'importantes études et d'une surveillance étroite des milieux marins et du biote aquatique dans le nord du Québec.

Les données présentées lors de l'atelier indiquent que l'écosystème marin du détroit d'Hudson, particulièrement à proximité des entrées est et ouest, est plus productif et biologiquement plus diversifié que celui de la baie d'Hudson et de la baie James. Plusieurs autres catégories de données permettent de croire que les écosystèmes productifs qui se trouvent aux entrées est et ouest du détroit diffèrent de par le caractère et la nature de leurs principaux réseaux trophiques. **Le comité directeur recommande par conséquent d'axer le programme de recherche autour d'un thème central constitué par une étude comparative détaillée de l'hydrodynamique et de la production biologique à proximité de celles-ci.** Des thèmes secondaires se rapportant aux préoccupations relatives au changement climatique, aux contaminants et aux aménagements hydroélectriques pourraient être structurés autour du corps comparatif principal. Ce programme pourrait nécessiter cinq à dix ans, mail il pourrait être divisé en deux ou trois étapes. **Le comité directeur recommande qu'un comité du programme, constitué des scientifiques qui oeuvrent dans les disciplines marines appropriées, soit mis sur pied le plus tôt possible et reçoive les pouvoirs nécessaires pour élaborer un programme de recherche plus détaillé qui pourrait être lancé au cours de l'année financière de 1992-1993.**

EXECUTIVE SUMMARY

Hudson Strait is a long, submerged valley lying north of 60° that separates Baffin Island in the Northwest Territories from the Ungava Peninsula of northern Quebec. It trends in a northwesterly direction from its eastern entrance and links the Labrador Sea and Davis Strait to Foxe Basin and Hudson Bay in the west. The length of the Strait is about 750 km and the average width is about 125 km, with a minimum of 70 km at the eastern entrance and a maximum of 240 km in the vicinity of Deception Bay to the west. Ungava Bay is a large, U-shaped body of water lying just within the eastern entrance and extending directly southward. It is 200 km wide at the mouth and extends 250 km southwards.

The native communities fringing Hudson Strait and Ungava Bay have long depended on the marine environment for much of their food. Historically, several species of marine mammals and anadromous fish constituted the principal harvests. Since about 1980 there has been a growing interest in a number of other marine species with a potential for small scale harvesting. This renewed interest in marine resources comes at a time of growing apprehension about the likely impacts on the marine ecosystem of various environmental threats. Of particular concern is the continuing hydroelectric development of major rivers that is altering the transport of freshwater, terrigenous organic matter and mercury into the marine environment of northern Quebec. It has been hypothesized that variations in the freshwater runoff significantly influence mixing processes in Hudson Strait and that this in turn affects biological production, not only within the Strait itself but also on the productive fishing grounds of the Labrador Shelf. There is also increasing uneasiness over the possibility that the atmospheric warming attributed to the greenhouse effect will cause significant changes in marine ecosystems, especially in these northern regions. The detection of pesticides, PCB's, cadmium and a wide range of other industrial contaminants in northern habitats and fauna is additional reason for concern.

The management, conservation and development of the marine resources in the region are subject to a number of outstanding claims as well as agreements defining the rights and obligations of the parties involved. The agreements specifically seek to ensure the protection of the resource species and their physical and biological environments in the face of development activities in the region. These management and conservation priorities are dependent on ongoing scientific research to provide information about the marine biota and habitats as well as to develop an understanding of the interrelationships among the key species constituting marine food chains. Fisheries research and development and the conduct of supporting physical, chemical and biological oceanographic research in these northern Quebec waters have thus been identified as important priorities by the Quebec Region of DFO and its clients. To date there have been few quantitative studies of the biota of the area and we know very little about the basic ecology of the marine populations and virtually nothing about the ecosystem processes that regulate them.

A significant increase in our understanding of the Strait's ecology will clearly require a substantial and sustained research effort. **It has therefore been proposed that a comprehensive multidisciplinary program of Marine Ecosystem Studies in Hudson Strait (MESHS) be initiated by the Quebec Region of DFO.** As a first step in developing such a program, arctic marine researchers from across Canada gathered in Montreal in November 1989 for a workshop on the marine ecosystem of Hudson Strait. The objectives of this workshop were to review the information presently available about the structure and functioning of the Hudson Strait marine ecosystem, pinpoint significant gaps in our knowledge and identify promising directions for future research. The available information was reviewed in a series of presentations in each of the following areas:

- Physical and chemical oceanography
- Phytoplankton, zooplankton and ice biota
- Fish and benthic invertebrates
- Marine birds
- Marine mammals
- Resource management

Participants were then divided into working groups to discuss research needs in terms of the following four general topics:

- Planktonic and ice production
- Fish and commercial invertebrates
- Marine birds and mammals
- Resource management and environmental impacts

The working groups identified existing data gaps and potential threats to northern marine ecosystems that need to be evaluated and monitored. An extensive list of possible studies in a wide variety of disciplines was developed.

A DFO Steering Committee has reviewed the draft Proceedings of the workshop and made recommendations regarding the further development of a program of Marine Ecosystem Studies in Hudson Strait. **The committee concluded that such a research program is justified, timely and feasible and should be further developed and initiated as soon as possible.** In view of the resource potential of the region and the many environmental threats to the ecosystem there is clearly a need for a great deal of further study and close monitoring of northern Québec marine environments and biota.

Evidence presented at the workshop indicates that the marine ecosystem of Hudson Strait, particularly in the vicinity of the eastern and western entrances, is more productive and biologically more diverse than that of Hudson Bay and James Bay. There are several lines of evidence that suggest that the productive ecosystems at the eastern and western entrances to the Strait are different in character, and in the nature of their major trophic pathways. **The Steering Committee therefore recommends that the research program be structured around a core theme involving a detailed comparative study of the hydrodynamics and biological production in the vicinity of the eastern and western entrances to Hudson Strait.** Sub-themes relating to developing concerns about climate change, contaminant inputs and hydroelectric developments could be structured around the principal comparative core. Such a program would require between 5 to 10 years to carry out, but could be divided into two or three phases. **The Steering Committee recommends that a Program Committee consisting of scientists active in the relevant marine disciplines be established as soon as possible and be given the responsibility for developing a more detailed research program to be initiated in the 1992-93 fiscal year.**

INTRODUCTION

Il incombe au MPO d'assurer et de coordonner la mise en oeuvre de la Stratégie de conservation du milieu marin de l'Arctique, que le Ministre considère comme prioritaire. Cette stratégie vise à préserver l'intégrité des écosystèmes marins de l'Arctique en favorisant l'enrichissement des connaissances et de l'information sur les milieux marins et l'utilisation des ressources qu'ils renferment. Elle touche notamment le détroit et la baie d'Hudson ainsi que la baie James.

Pour les autorités de la Région du Québec du MPO et pour ses clients, les activités de recherche et développement en matière de pêches et la recherche en océanographie dans les eaux du Nouveau-Québec constituent d'importants objectifs. Les eaux du détroit d'Hudson, soumises à un fort brassage, sont très productives, comme en témoigne l'abondance de mammifères marins, d'oiseaux et de poissons. Certaines espèces jouent depuis longtemps un grand rôle dans l'économie des communautés inuit en bordure du détroit. On trouve également, dans la région, diverses autres espèces marines qui présentent un potentiel d'exploitation durable sur une petite échelle, notamment les crevettes, les pétoncles, les moules et le turbot (flétan du Groënland). Cela a incité de plus en plus de collectivités locales à accroître l'exploitation des ressources marines. Toutefois, pour assurer un rendement soutenu, il faudra surveiller et gérer avec soin les stocks eux-mêmes et acquérir une connaissance approfondie de leur environnement tant biotique qu'abiotique. Or, jusqu'à présent, on a exécuté peu d'études quantitatives du biote de la région arctique, de sorte qu'on connaît très peu de choses sur l'écologie de base des populations marines et presque rien sur les processus de l'écosystème qui influent sur ces populations.

Le détroit d'Hudson constitue un écosystème marin vaste et complexe. Pour enrichir de façon significative nos connaissances sur son écologie, il faudra de toute évidence déployer un effort de recherche considérable et soutenu. Il a été proposé que la Région du Québec du MPO instaure un programme multidisciplinaire global d'études de l'écosystème marin du détroit d'Hudson.

Une première étape dans la mise en oeuvre d'un tel programme de recherche a été franchie les 8 et 9 novembre, à Montréal, avec la tenue d'un atelier sur la biologie marine et l'océanographie du détroit d'Hudson, qui a réuni les chercheurs de tout le Canada, spécialisés dans les milieux marins de l'Arctique et particulièrement dans les écosystèmes marins du Nord. Cet atelier comportait plusieurs objectifs: premièrement, faire le point sur les connaissances actuelles dans les domaines de la structure et du fonctionnement de l'écosystème marin du détroit d'Hudson et mettre en évidence les lacunes majeures; deuxièmement, déterminer les besoins actuels et futurs en informations concernant la gestion des ressources et les impacts éventuels des projets d'aménagement hydroélectrique sur le milieu marin; troisièmement, définir des orientations prometteuses pour la recherche future en océanographie et en biologie marine dans la région; et enfin, jouer un rôle de catalyseur pour encourager et faciliter un dialogue permanent et assurer la coopération entre les chercheurs spécialisés dans les milieux marins et les gestionnaires des pêches en poste dans la région.

Au cours de la première journée, les présidents des séances ont examiné l'information existante sur a) l'océanographie physique et chimique; b) la production primaire et secondaire du plancton, c) les ressources halieutiques et d) les stocks de mammifères marins et les oiseaux de mer de la région. D'autres chercheurs ont ensuite présenté les résultats d'études récentes ou en cours.

La seconde journée, les participants se sont répartis en quatre groupes de travail pour traiter des besoins de recherche et envisager des orientations prometteuses pour les futurs travaux de recherche portant sur i) le plancton et le biote des glaces de mer; ii) les poissons et les invertébrés d'importance commerciale; iii) les mammifères marins et les oiseaux de mer, et iv) la gestion des ressources et les impacts sur l'environnement.

Le présent volume fait la synthèse des diverses informations présentées à l'atelier. Il comprend les analyes documentaires de la recherche dans des disciplines choisies, les résumés des communications, les compte rendus sommaires des discussions des groupes de travail et de la réunion plénière ainsi que les recommandations du comité directeur pour l'orientation générale de la recherche dans la région.

INTRODUCTION

The Department of Fisheries and Oceans has the responsibility for coordinating and implementing the Government's Arctic Marine Conservation Strategy (AMCS), and the Minister has identified this as a departmental priority. The AMCS seeks to "ensure the future health and well being of arctic marine ecosystems" by promoting "development of knowledge, information and understanding of marine systems and resource use". The area encompassed by the AMCS includes Hudson Strait as well as Hudson and James Bays.

Fisheries research and development as well as oceanographic research in these northern Quebec waters have been identified as important objectives by the Quebec Region of DFO and its clients. The abundance of marine mammals, seabirds, and fish in Hudson Strait clearly show that these well-mixed waters are productive. A number of species have long been important to the economy of the Inuit communities fringing the Strait. A variety of other marine species with a potential for sustainable small-scale harvesting such as shrimp, scallops, mussels, and turbot (Greenland halibut) are also found in the area. This has stimulated a growing interest among local communities in expanding their marine harvest. Ensuring a sustainable harvest, however, will require careful monitoring and management of the stocks themselves, as well as sound knowledge of their biotic and abiotic environment. To date there have been few quantitative studies of the biota of the area and we know little about the basic ecology of the marine populations and virtually nothing about the ecosystem processes that sustain and regulate them.

Hudson Strait is a large and complex marine ecosystem. A significant increase in our understanding of its ecology will clearly require a substantial and sustained research effort. It has been proposed that a comprehensive multidisciplinary program of Marine Ecosystem Studies in Hudson Strait (MESHS) be initiated by the Quebec Region of DFO.

As an initial step in the development of such a research program, arctic marine scientists from across Canada, with particular interests in northern marine ecosystems got together on November 9 and 10, 1989 in Montreal for a workshop on the marine biology and oceanography of Hudson Strait. The workshop had several objectives: first, to review the information presently available about the structure and functioning of the Hudson Strait marine ecosystem and to pinpoint significant gaps in our knowledge; second, to identify present and future information needs relating to the management of resource species and to the potential impacts on the marine environment of northern hydroelectic developments; third, to identify promising directions for future oceanographic and marine biological research in the area; and finally, to serve as a catalyst to encourage and facilitate ongoing dialogue and cooperation among marine researchers and fisheries managers working in the area.

During the first day, session chairmen reviewed the available information about a) the physical and chemical oceanography, b) the primary and secondary plankton production, c) the fisheries resources and d) the marine mammal stocks and seabirds of the region. Other researchers then presented the results of recent or ongoing studies.

On the second day, participants divided into four working groups to discuss information needs and to consider promising directions for future research in relation to i) plankton and sea-ice biota, ii) fish and commercial invertebrates, iii) marine mammals and seabirds, and iv) resource management and environmental impacts.

To make the document more "user friendly" for busy research managers the original order of the workshop presentations has been largely reversed. Thus, the concluding recommendations of the Steering Committee precede the working group reports which in turn precede the reviews of research in selected marine disciplines and the abstracts of the papers presented at the workshop.

MOT D'OUVERTURE A L'OCCASION DU COLLOQUE

Jean Boulva

Directeur régional, Sciences
Pêches et Océans, Région du Québec

La région du Québec du MPO a convenu d'organiser cet atelier sur le détroit d'Hudson, dont le principal objectif est de faire le point sur nos connaissances de cette région de l'Arctique et de proposer un programme pluriannuel de recherche. Notre Ministère accorde un intérêt primordial aux eaux marines de l'Arctique canadien. Il a pour mandat de gérer ses ressources et de protéger son écosystème fragile constitué d'une flore et d'une faune unique.

Le détroit d'Hudson est la principale voie qui assure la circulation de l'eau entre l'océan Atlantique et un vaste système estuarien comprenant les baies d'Hudson et James ainsi que le bassin Foxe. Il assure un habitat aux principales colonies d'oiseaux de mer, aux baleines, aux phoques, aux morses, aux poissons et aux populations d'invertébrés, notamment certaines espèces qui présentent un intérêt commercial, comme la morue, le turbot, les crevettes, les pétoncles et le saumon.

La connaissance des processus biologiques qui préservent la productivité de cette vaste région marine est une condition essentielle pour les personnes chargées de conseiller les gestionnaires. Nous devons obtenir rapidement les informations suffisantes sur les nombreuses perturbations prévues dans un avenir proche et plus lointain. Pensons au réchauffement global de l'atmosphère, à la pénétration croissante des rayons ultra-violet à la surface de la mer, à la migration des polluants vers le nord, à l'exploitation intense de certaines espèces marines arctiques, à la perturbation physique du biote des glaces par le transport dans les eaux arctiques et aux effets cumulatifs des barrages de rivières pour la production de l'électricité. Ces exemples montrent pourquoi il faudrait enrichir rapidement nos connaissances sur les écosystèmes marins de l'Arctique en général, et sur ceux du détroit d'Hudson en particulier. A cette fin, nous devrons faire appel aux physiciens, aux chimistes ainsi qu'aux biologistes, solliciter le concours de chercheurs qui se consacrent, pendant de nombreuses années, à l'exécution de travaux difficiles sur le terrain, obtenir la coopération d'universités, des gouvernements, du secteur privé ainsi que le soutien des communautés du Nord.

Avant d'entreprendre un projet d'une telle envergure, il est nécessaire de faire le point sur l'état actuel des connaissances, de déterminer les priorités en matière de recherche et c'est ce qui explique notre réunion durant ces deux journées. Comme l'a mentionné le ministre de l'Environnement, l'Honorable Lucien Bouchard, dans une allocution au Symposium sur le Saint-Laurent en novembre 1989 à Montréal, notre régime de gestion des ressources et de l'environnement dans l'Arctique doit être fondé sur des connaissances scientifiques à jour.

Dans le domaine des eaux marines, le MPO a pour mandat formel de jouer un rôle de chef de file dans l'exécution de la recherche marine et il s'est d'ailleurs parfaitement acquitté de cette tâche dans l'Arctique depuis de nombreuses décennies. Plusieurs Régions administratives apportent leur participation: la Région centrale et Arctique à Winnipeg, la Région de Terre-Neuve pour la côte du Labrador, la Région du Québec pour le Nouveau-Québec et les eaux adjacentes et la Région Scotia-Fundy avec un centre hautement spécialisé à l'Institut océanographique de Bedford.

Comme on peut le voir, il y a de bonnes raisons pour initier un programme majeur de recherche océanographique dans cette région. Il faut aussi signaler au niveau international la contribution du Canada en vue d'une meilleure connaissance de l'Arctique. La participation canadienne aux activités du Arctic Ocean Science Board et à la formation du Comité international des Sciences dans l'Arctique ainsi que la contribution de nos spécialistes à l'élaboration du Programme International sur les Polynies sont autant de témoignages du désir de notre pays d'être un partenaire actif de l'initiative présentement en cours en vue de l'étude des mers arctiques. Le projet du Détroit d'Hudson est une contribution supplémentaire à l'ensemble de ces initiatives importantes. Dans le contexte de la rareté des ressources, il importe de le bien définir, de bien l'aligner sur les besoins des populations nordiques et sur ceux des gestionnaires de l'environnement arctique.

WORKSHOP OPENING REMARKS

Jean Boulva

Regional Director, Science
Fisheries and Oceans - Quebec Region

This workshop on Hudson Strait, the main objective of which is to assess our knowledge of this area of the Arctic and propose a multi-year research program, has been organized by DFO's Quebec Region. Our Department has a keen interest in the waters of the Canadian Arctic, where we are responsible for managing resources and protecting the fragile ecosystem, with its unique flora and fauna.

Hudson Strait is the main artery for the flow of water between the Atlantic Ocean and the extensive estuarine-driven system of Hudson Bay, James Bay, and Foxe Basin. It is home to large colonies of seabirds, whales, seals, walruses, fish and invertebrates; including some, such as cod, turbot, shrimp, scallops and salmon, which are commercially exploited.

It is essential that those responsible for advising managers, understand the biological processes which maintain the productivity of this vast marine area. We must quickly obtain adequate information about the many disturbances anticipated in the short and long terms, including global warming of the atmosphere, the increasing penetration of the ocean surface by ultra-violet rays, the northward migration of pollutants, the intensive exploitation of certain arctic marine species, the physical disturbance of ice biota by arctic sea transport and the cumulative effects of damming rivers to produce electricity. These are examples of why we need to move quickly to improve our understanding of arctic marine ecosystems in general, and Hudson Strait in particular. This will require the attenion of physicists, chemists and biologists, many years of dedicated field work by scientists, the co-operation of universities, governments and the private sector, as well as the support of people living in the North.

Before undertaking a project of this magnitude, current knowledge should be reviewed and research priorities examined. This is the purpose of our meeting over the next two days. As mentioned by the Honourable Lucien Bouchard, Minister of the Environment, in a speech at the Symposium on the St. Lawrence River in Montreal in November 1989, our arctic environmental and resource management plan must be based on up-to-date scientific knowledge.

In the case of marine waters, DFO has a clear mandate to provide leadership in marine research, as it has done in the Arctic for many decades. Many of our administrative regions are involved, including the Central and Arctic Region based in Winnipeg, the Newfoundland Region for the Labrador coast, the Quebec Region for northern Quebec and adjacent waters and the Scotia-Fundy Region, with the considerable northern expertise of the Bedford Institute of Oceanography.

As we can see, there are good reasons for initiating a major oceanographic research program in the area. International attention should also be drawn to Canada's contribution to improved knowledge of the Arctic. Our country's participation in Arctic Ocean Science Board activities and in setting up the

International Arctic Science Committee, as well as the contribution of our specialists in preparing the International Program on Polynyas testify to Canada's desire to be an active partner in current initiatives to study arctic waters. The Hudson Strait project is an additional contribution to these important initiatives. In light of the scarcity of resources it is important that we define the project clearly, and ensure that it meets the needs of northern populations and managers of arctic marine resources and habitats.

RECOMMANDATIONS DU COMITÉ DIRECTEUR

INTRODUCTION

Le comité directeur[1] s'est réuni le 23 août 1990 pour étudier la version préliminaire du compte rendu de l'atelier et faire des recommandations concernant l'élaboration d'un programme **d'Études sur l'écosystème marin du détroit d'Hudson**. Le comité a conclu que l'atelier avait été très fructueux étant donné que de l'information très intéressante était présentée et étudiée, et que de nombreuses excellentes ideés de projets de recherche ont été lancées. Le compte rendu constitue un document utile qui résume de façon concise une grande partie de l'information disponible sur l'écosystème marin du détroit d'Hudson et identifie de nombreuses lacunes importantes au niveau de nos connaissances. Il ne constitue cependant pas en soi un programme de recherche intégré. Il fournit néanmoins un cadre sûr pour l'élaboration d'un programme détaillé d'étude des pêcheries, des mammifères marins et de l'océanographie physique, chimique et biologique de la région. **Le comité croit fermement qu'un tel programme de recherche est justifié, opportun et faisable**.

La présentation qui suit 1) justifie qu'il faut mener ce programme de recherche dès maintenant, 2) décrit brièvement l'orientation principale et l'étendue générale du programme de recherche proposé et 3) suggère la composition et le mandat d'un groupe de travail spécial mis sur pied dans le but de préparer une proposition détaillée d'un progamme de recherche multidisciplinaire pluriannuel, et de superviser sa mise en application.

JUSTIFICATION DU PROGRAMME

Les mammifères marins, la sauvagine et les poissons anadromes sont depuis longtemps très importants pour l'économie des collectivités côtières qui se trouvent sur le bord du détroit d'Hudson et du nord de la baie d'Hudson. On a récemment porté un intérêt considérable à l'exploitation d'autres espèces marines abondantes dans cette région, comme le flétan du Groënland, les crevettes, les pétoncles et les moules. Cet intérêt renouvelé pour la récolte des ressources marines arrive cependant à un moment d'appréhension croissante au sujet des impacts possibles des diverses menaces environnementales sur l'écosystème marin.

On se préoccupe particulièrement de l'aménagement hydroélectrique continuel des principales rivières qui modifie le transport de l'eau douce, des matières organiques terrigènes et du mercure dans les eaux marines du nord québécois. On ne connaît pas encore les effets possibles à long terme sur les écosystèmes des changements au niveau du déversement de ces eaux douces et de l'introduction de produits chimiques toxiques dans la baie James et la baie d'Hudson. Les preuves d'effets locaux s'accumulent lentement dans les estuaires et les eaux côtières voisines. Cependant, les effets sur les parties plus larges de la baie d'Hudson, du détroit d'Hudson et du plateau continental du Labrador font encore partie du domaine de l'hypothèse.

---

[1] La liste des membres du comité se trouve à la page 169.

Les processus d'océanographie physique jouent nettement un rôle important en influant sur la composition et la production des espèces dans différentes régions du nord du Québec. Les deux processus les plus évidents sont la variation saisonnière des interactions complexes entre les masses d'eau marines de l'Arctique et de l'Atlantique nord. L'intrusion de l'eau de l'Atlantique dans l'extrémité est du détroit et le volume de l'écoulement d'eau douce dans la baie d'Hudson entrant par l'extrémité ouest du détroit varient de façon saisonnière et fluctuent sur de longues périodes de temps. On a supposé que le degré de pénétration de l'eau de l'Atlantique est inversement proportionnel au volume d'eau douce qui y est déversé. On croit également que les processus de brassage à l'intérieur du détroit sont influencés par les fluctuations du débit sortant et, le cas échéant, la production biologique dans différentes régions pourrait également être touchée.

SUTCLIFFE *et al.* (1983) ont également trouvé que les substances nutritives mélangées à l'eau de surface dans l'est du détroit d'Hudson sont injectées dans le courant qui s'écoule vers le sud en passant sur le plateau continental du Labrador, ce qui fait que la concentration de nitrate au sud du détroit est plus du double de celle que l'on retrouve au nord. Ils ont de plus supposé que ces matières nutritives ajoutées favorisent le développement d'une chaîne trophique qui contribue considérablement aux pêches dans la partie sud du plateau continental du Labrador et probablement sur le Grand Banc. Ils prétendent que ce processus de mélange et de transport des substances nutritives pourrait être influencé par les fluctuations de l'écoulement de l'eau douce dans la baie d'Hudson. Il y a donc tout lieu de croire que l'écosystème marin d'une grande région pourrait être influencé par les changements progressifs de l'écoulement des eaux douces résultant du changement climatique, de la dérivation d'importantes rivières ou de la réalisation du projet Grand Canal.

On se préoccupe également de plus en plus de la possibilité que le réchauffement atmosphérique dû à l'effet de serre entraîne des changements importants au niveau des écosystèmes marins, principalement dans les régions nordiques. Cela pourrait entraîner des changements au niveau du déversement des eaux douces du vaste bassin hydrographique de la baie d'Hudson ainsi qu'un réchauffement direct de la mer elle-même. Le fait que le détroit d'Hudson soit un écosystème subarctique, avec de nombreuses espèces nord-atlantiques vivant près des limites septentrionales de leur aire de répartition et de nombreuses espèces arctiques vivant près des limites méridionales de leur aire de répartition, suppose que de nombreuses populations seront particulièrement sensibles à de très faibles changements au niveau de la température de la mer.

La détection de pesticides, de BPC, de cadmium et d'une vaste gamme d'autres contaminants industriels dans les habitants et la faune nordiques constitue une autre raison de s'inquiéter. Un grand nombre de ces contaminants ne sont pas produits localement mais sont le résultat du transport atmosphérique sur de longues distances à partir des régions industrialisées du sud. Cette contamination prépondérante de la chaîne alimentaire marine de l'Arctique est particulièrement inquiétante étant donné que les résidants du Nord puisent la majeure partie de leur nourriture dans la mer.

La gestion, la conservation et la mise en valeur des ressources marines de la région sont sujettes à des revendications territoriales en suspens ainsi qu'à des accords définissant les droits et les obligations des parties en cause. Les accords cherchent principalement à assurer la protection des espèces ressources et de leurs milieux physiques et biologiques malgré les activités de développement dans la région. Ces priorités en matière de gestion et de conservation dépendent de la recherche scientifique permanente pour fournir des informations sur le biote marin et ses habitats, et pour mieux faire comprendre les rapports qui existent entre les espèces-clés qui constituent des chaînes trophiques marines. La recherche et le développement en matière de pêche et la recherche connexe en océanographie physique, chimique et biologique de ces eaux du nord du Québec sont donc considérés comme d'importantes priorités par la région du Québec du MPO et ses clients. Jusqu'à présent, il y a eu très peu de recherche sur le biote, et nous connaissons très peu l'écologie de base des populations marines, et presque rien des processus de l'écosystème qui les régissent.

PROGRAMME DE RECHERCHE RECOMMANDÉ

Pour mieux comprendre l'hydrographie et l'écologie du détroit d'Hudson, il faudra de toute évidence mettre sur pied un programme de recherche étoffé et soutenu. **Le comité directeur recommande donc que la région du Québec du MPO élabore et mettre en oeuvre aussitôt que possible un programme multidisciplinaire global d'études de l'écosystème marin dans le détroit d'Hudson (EEMDM).** En sus de la participation de la région du Québec du MPO au programme d'études et de son rôle de direction générale à cet égard, il est essentiel que l'on invite des chercheurs intéressés d'autres régions du MPO (en particulier ceux de la région de Terre-Neuve), d'autres ministères gouvernementaux (spécialement le Service canadien de la faune) et des universités à participer à la planification et à l'exécution du programme d'études. On devrait concevoir le programme d'études de façon à ce qu'il améliore notre connaissance générale de l'océanographie et des processus de production biologique de cette importante région, et ce afin que l'on puisse régler de façon plus efficace les nombreux problèmes liés à la gestion des ressources et à la protection de l'environnement.

Les données présentées lors de l'atelier montrent que l'écosystème marin du détroit d'Hudson, en particulier près des entrées est et ouest, est plus productif et plus varié sur le plan biologique que celui de la baie d'Hudson et de la baie James. Il est certain que ce sont là deux zones importantes pour l'exploitation des ressources marines. Dans l'entrée est du détroit, il semble y avoir des stocks de poissons et d'invertébrés marins dont l'intérêt commercial est davantage prometteur, tandis que, dans l'entrée ouest du détroit, on trouve principalement des mammifères marins et des populations d'oiseaux marins. Cette différence entre les zones est et ouest est intéressante si on l'analyse à la lumière de l'hypothèse de DUNBAR (1966) qui veut que, dans les eaux situées plus au nord dans l'Arctique, les mammifères marins, plutôt que les poissons marins, aient tendance à dominer les niveaux supérieurs de la chaîne alimentaire. Les communautés de poissons vivant dans la zone ouest possèdent certainement davantage de caractères des populations arctiques que celles vivant dans la zone est. Il y a plusieurs autres catégories de données qui permettent de croire que les écosystèmes productifs des entrées est et ouest du détroit diffèrent également de par les caractères et la nature de leurs principaux réseaux trophiques. Certains émettent l'hypothèse que, du côté ouest, une plus grande proportion de la production est recyclée par l'entremise du benthos, tandis que, du côté est, la circulation de la matière est à prédominance pélagique. C'est là une différence prévisible, si l'on se reporte aux travaux de PETERSEN et CURTIS (1980) qui mentionnent que la proportion de la matière recyclée par l'entremise du benthos a tendance à s'accroître lorsqu'on passe des régions tropicales aux régions subarctiques. La prédominance de morses se nourrissant d'organismes benthiques dans l'entrée ouest et de crevettes et de bélugas se nourrissant d'organismes pélagiques dans l'entrée est milite en faveur de cette hypothèse.

Le comité directeur recommande, par conséquent, d'axer le programme de recherche autour d'un thème central constitué par une étude comparative détaillée de l'hydrodynamique et de la production biologique à proximité des entrées est et ouest du détroit d'Hudson. Il faudrait formuler des hypothèses plus précises quant à la nature, à la portée et à la cause des différences posées comme postulat entre les deux zones. Le programme de recherche devrait également fournir des renseignements sur la façon de gérer ces ressources renouvelables et de surveiller et de protéger l'environnement. On pourrait développer, autour du thème principal, des thèmes secondaires axés sur les préoccupations croissantes au sujet des changements climatiques, des contaminants et de l'aménagement hydroélectrique.

La stratégie globale consisterait à mettre au point un programme de recherche intégré et général qui permettrait de coordonner dans la mesure du possible les études proposées et en cours. Dans presque toutes les disciplines, il faudra également faire certaines études descriptives de base. Il faudra entre cinq et dix ans pour exécuter intégralement un tel programme, mais on pourrait le diviser en deux ou trois phases.

Il sera nécessaire de définir avec précision deux secteurs de recherche, un à chaque entrée du détroit. Afin de restreindre les recherches à une zone de dimension pratique, il faudra peut-être exclure de la phase initiale de l'étude une grande partie de la baie d'Ungava. Étant donné l'information fragmentaire sur ces zones dont nous disposons à l'heure actuelle, il faudra que le programme soit doté d'une grande souplesse initiale afin qu'on puisse le modifier à mesure que notre connaissance de la région s'améliorera. Il ne sera peut-être pas possible de choisir dès le départ des stations d'observation précises, si cela s'avérait nécessaire. Il faudra envisager de mener une étude préliminaire générale au cours des deux premières campagnes sur le terrain. Cela suppose le prélèvement d'échantillons dans une série de transects dans les zones est et ouest du détroit au cours de deux saisons différentes. De toute évidence, cet échantillonnage nécessitera l'utilisation d'au moins un gros navire de recherche pendant plusieurs semaines. On pourrait examiner la possibilité d'utiliser des navires auxiliaires occasionnels pour l'exécution de certaines parties du programme. Il sera nécessaire de faire des travaux multidisciplinaires d'envergure pour mener à bien la plus grande partie du programme, mais il faudra également prévoir de travailler de façon plus intensive sur une plus petite échelle pour l'étude de processus précis. Il n'est pas rentable de faire des échantillonnages répétitifs dans une petite zone sur de longues périodes en se servant d'un gros navire qui sera basé dans le Nord, comme celui que l'on est en voie de construire pour remplacer le Calanus, tout particulièrement dans le cas où les opérations seraient menées à partir d'un laboratoire terrestre et d'un hélicoptère pour les travaux menés sur le terrain en hiver et au printemps ainsi que pour certaines études de processus de longue durée menées pendant toute l'année dans des secteurs bien circonscrits. L'utilisation d'hélicopères sera obligatoire pour toute étude saisonnière, car les navires ne peuvent servir aux travaux d'échantillonnage que pendant deux à trois mois par année. Le recours aux hélicoptères fera augmenter de façon considérable le coût du projet.

De toute évidence, le niveau actuel des ressources allouées à la région du Québec du MPO pour les programmes du Nord ne suffit pas pour l'exécution d'un programme de recherche de l'ampleur et de la durée proposées. Il faudra très certainement obtenir des fonds supplémentaires importants. On pourrait peut-être obtenir une partie de ces fonds en faisant valoir la nécessité d'étudier l'impact des aménagements hydroélectriques et certains aspects de la mise en valeur des pêcheries.

MISE SUR PIED D'UN COMITÉ DU PROGRAMME

Le comité directeur recommande que l'on mette sur pied aussitôt que possible un comité du programme et qu'on le charge d'établir un programme de recherche plus détaillé. Le mandat du comité du programme comprendrait les éléments suivants:

1. Coordonner l'élaboration d'un programme de recherche global en se fondant sur les recommandations générales du comité directeur énoncées dans les paragraphes précédents. En d'autres mots, le programme devrait comprendre une analyse et une comparaison détaillées des écosystèmes à proximité des entrées est et ouest du détroit d'Hudson. Il devrait être possible d'exécuter la première phase d'un tel programme d'ici environ cinq ans, en supposant que le financement et les autres formes de soutien sont suffisants. Tout en élaborant le programme général, le comité du programme devrait envisager d'inclure des études orientées sur les thèmes secondaires suivants:

    a) La gestion des stocks exploitables ou la compréhension des réseaux trophiques liant les stocks exploitables.

    b) La sensibilité de l'écosystème marin aux travaux d'aménagement hydroélectrique dans le nord du Québec et les répercussions en aval des modifications de l'écoulement des eaux douces dans la baie d'Hudson. L'hypothèse de SUTCLIFFE *et al.* (1983) qui établit des liens entre le débit sortant de la baie d'Hudson, le brassage des eaux dans le détroit d'Hudson et les pêcheries de la côte est serait analysée plus en détail dans cette section du programme. Le Comité du programme devrait consulter les chercheurs des laboratoires de la côte est à ce sujet.

c) La sensibilité de l'écosystème aux changements climatiques, en particulier ceux qui sont transmis par les modifications du débit sortant de la baie d'Hudson.

d) La sensibilité de l'écosystème aux contaminants pénétrant dans la baie d'Hudson.

2. Rédiger un énoncé plus élaboré justifiant la nécessité pour le MPO de considérer comme prioritaire le programme de recherche.

3. Établir un calendrier proposant des dates limites clés pour l'élaboration et la mise en oeuvre du programme.

4. Établir un plan logistique résumant le soutien nécessaire au programme. On y trouverait, entre autres, des recommandations sur la taille et l'emplacement des stations d'observations et sur le genre de navire requis.

5. Recommander un budget approximatif pour les diverses composantes du programme, lequel comprendrait une liste des immobilisations nécessaires et leur coût.

6. Identifier les sources de financement possibles pour le programme de recherche.

7. Soumettre, dans les six mois suivant la mise sur pied du comité, un rapport préliminaire présentant en détail le programme de recherche proposé. On distribuera le rapport du comité du programme aux membres du comité directeur, aux chercheurs participant au programme, à la haute direction du MPO et aux groupes clients intéressés (Hydro Québec, Makivik Corp., etc.) afin d'obtenir leurs commentaires et leurs suggestions. On vise à disposer d'un plan de programme suffisamment étoffé pour que l'on puisse le présenter comme un plan de travail pouvant être mis en oeuvre au cours de l'année financière 1992-1993.

Le comité du programme devrait être formé de chercheurs qui seront probablement appelés à participer au programme de recherche proposé dans le détroit d'Hudson. Il devrait y avoir au moins un membre représentant chacune des diverses disciplines en cause, notamment:

océanographie physique
océanographie chimique
océanographie biologique
ichtyologie
mammologie marine
ornithologie marine
météorologie

Le comité directuer soumettra, à l'approbation de la direction, une liste de noms de personnes qu'il propose comme membres et président du comité du programme. Les membres du comité du programme devraient consulter autant que possible la plupart des autres chercheurs dans leur propre discipline qui pourraient être intéressés à participer directement ou indirectement au programme de recherche, afin de mettre au point un programme de recherche aussi global que possible.

RÉFÉRENCES

DUNBAR, M.J. 1966. The seawaters surrounding the Quebec-Labrador peninsula. **Cah. Géogr. Québec.** 19:13-35.

PETERSEN, G.H. & M.A. CURTIS. 1980. Differences in energy flow through major components of subarctic, temperate and tropical marine shelf ecosystems. **Dana** 1:53-64.

SUTCLIFFE, W.H. Jr., R.H. LOUCKS, K.F. DRINKWATER & A.R. COOTE. 1983. Nutrient flux onto the Labrador Shelf from Hudson Strait and its biological consequences. **Can. J. Fish. Aquat. Sci.** 40:1692-1701.

RECOMMENDATIONS OF STEERING COMMITTEE

INTRODUCTION

The Steering Committee[1] met on August 23, 1990 to review the draft proceedings of the workshop and make recommendations regarding the further development of a program of **Marine Ecosystem Studies in Hudson Strait**. The committee concluded that the Workshop was very successful in that much interesting information was presented and discussed and many excellent ideas for research projects were generated. The resulting Proceedings form a useful document that concisely summarizes a great deal of the available information about the Hudson Strait marine ecosystem and identifies many important gaps in our knowledge. However, it does not in itself constitute an integrated research program. It, nevertheless, provides a sound framework for the development of a comprehensive program to study the physical, chemical, and biological oceanography and fisheries ecology of the region. **The committee strongly believes that such a research program is justified, timely and feasible.**

The following presentation: 1) outlines the justification for carrying out such research at the present time, 2) briefly describes the main thrust and general scope of a suggested research program and 3) details the composition and mandate of a special working group that would be established to prepare a comprehensive proposal for a multiyear, multidisciplinary research program and oversee its implementation.

PROGRAM JUSTIFICATION

Marine mammals, waterfowl and anadromous fish have long been important to the economies of the coastal communities bordering Hudson Strait and northern Hudson Bay. Recently, considerable interest has also developed in the harvesting of other locally abundant marine species, such as Greenland halibut, shrimp, scallops and mussels. This renewed interest in the harvesting of marine resources, however, comes at a time of growing apprehension about the likely impacts on the marine ecosystem of various environmental threats.

Of particular concern is the continuing hydroelectric development of major rivers that is altering the transport of freshwater, terrigenous organic matter and mercury into the marine waters of northern Quebec. The possible long term effects on northern ecosystems of changes in freshwater discharge and the introduction of toxic chemicals into James and Hudson Bays are not yet known. Evidence for local effects in estuaries and nearby coastal waters is slowly accumulating. However, the effects over the wider reaches of Hudson Bay, Hudson Strait and the Labrador Shelf are still largely a matter of conjecture.

Physical oceanographic processes clearly play a major role in influencing both species composition and production in different areas of northern Quebec. The two most conspicuous of these processes are the seasonally varying interplay between freshwater runoff and marine water and the complex interactions between

---

[1] Committee members listed on page 169.

marine water masses of Arctic and North Atlantic origin. The intrusion of Atlantic water into the eastern end of the Strait and the volume of freshwater runoff into Hudson Bay entering the western end of the Strait vary seasonally and also fluctuate over longer time periods. It has been suggested that the degree of penetration of Atlantic water varies inversely with the volume of freshwater discharged. Mixing processes within the Strait are also thought to be influenced by the fluctuations in freshwater outflow and, if so, then biological production in different areas could also be affected.

SUTCLIFFE *et al.* (1983) have also found that nutrients mixed into the surface water in eastern Hudson Strait are injected into the current flowing southward over the Labrador Shelf. As a result, the nitrate concentration south of the Strait is more than double that to the north. They have further hypothesized that these added nutrients enhance the development of a food chain that contributes significantly to the fisheries on the southern Labrador Shelf and possibly the Grand Banks. They argue that this mixing and nutrient transport process could be influenced by fluctuations in freshwater discharge into Hudson Bay. Thus, the marine ecosystem of a large region could conceivably be influenced by progressive changes in freshwater runoff that could result from climate change, major river diversions or implementation of the Grand Canal Project.

There is also increasing uneasiness over the possibility that the atmospheric warming stemming from the greenhouse effect will cause significant changes in marine ecosystems, especially in these northern regions. This could result from changes in the discharge of freshwater from the huge Hudson Bay watershed as well as from a direct warming of the sea itself. The fact that Hudson Strait is a subarctic ecosystem, with many north Atlantic species near the northern limits of their range of distribution and many arctic species near their southern limit of distribution, suggests that many populations may be particularly sensitive to even small changes in sea temperature.

The detection of pesticides, PCB's, cadmium and a wide range of other industrial contaminants in northern habitats and fauna is additional reason for concern. Many of these are clearly not of local origin but are a result of long-distance atmospheric transport from highly industrialized areas. Such pervasive contamination of the arctic marine food chain is particularly worrisome because northern residents derive much of their food from the sea.

The management, conservation and development of the marine resources in the region are subject to a number of outstanding claims and legal agreements defining the rights and obligations of the various parties involved. The agreements specifically seek to ensure the protection of the resource species and their physical and biological environments in the face of development activities in the region. These management and conservation priorities are dependent on ongoing scientific research to provide information about the marine biota and their habitats as well as to develop an understanding of the interrelationships among the key species constituting marine food chains. Fisheries research and development and the conduct of supporting physical, chemical and biological oceanographic research in these northern Quebec waters have thus been identified as important priorities by the Quebec Region of DFO and its clients. To date there have been few quantitative studies of the biota of the area and we know very little about the basic ecology of the marine populations and virtually nothing about the ecosystem processes that regulate them.

RECOMMENDED RESEARCH PROGRAM

A significant increase in our understanding of the hydrography and ecology of Hudson Strait will clearly require a substantial and sustained research effort. **It is therefore recommended that a comprehensive multidisciplinary program of Marine Ecosystem Studies in Hudson Strait (MESHS) be developed and initiated by the Quebec Region of DFO as soon as feasible.** Although the Quebec region of DFO would be involved in the study and provide overall leadership, it is imperative that interested researchers from other regions of DFO (particularly the Newfoundland region), other government departments (particularly the Canadian Wildlife Service) and universities also be invited to participate in the planning and execution of the program. The proposed program should be designed to enhance our general understanding of the oceanographic and biological production processes of this important region and thus permit us to address more adequately the many concerns regarding resource management and environmental impacts.

Evidence presented at the Workshop indicates that the marine ecosystem of Hudson Strait, particularly in the vicinity of the eastern and western entrances, is more productive and biologically more diverse than that of Hudson Bay and James Bay. Hudson Strait is important from the point of view of harvesting marine resources. The eastern Strait appears to have the more promising stocks of marine fish and invertebrates of commercial interest, while marine mammals and seabird populations appear to predominate at the western end. This difference is interesting in the light of DUNBAR's (1966) suggestion that in more arctic waters marine mammals rather than marine fish tend to dominate the upper levels of the food chain. The fish communities in the west are more arctic in character than those in the east. There are several other lines of evidence that suggest that the productive ecosystems at the eastern and western entrances to the Strait are different in character and in the nature of their major trophic pathways. There is some indication that in the west a greater proportion of production is cycled through the benthos, while in the east more is retained within the pelagic community. This is a predictable contrast, following upon the work of PETERSEN and CURTIS (1980) that suggests that the proportion of production cycling through the benthos tends to increase from tropics to subarctic. The predominance of benthic feeding walruses in the western Strait and of pelagic feeding shrimps and belugas in the east have been cited in support of this hypothesis.

The Steering Committee therefore recommends that the research program be developed around a core theme involving a detailed comparative study of the hydrodynamics and biological production in the vicinity of the eastern and western entrances to Hudson Strait. More specific hypotheses should be developed to explore the nature, extent and cause of the postulated differences between the two regions. The research program developed must also provide information relevant to renewable resource management and environmental monitoring and protection. Sub-themes relating to developing concerns about climate change, contaminant inputs and hydroelectric developments could be structured around the principal comparative core.

The overall strategy should be to develop a comprehensive integrated research program that will coordinate proposed and existing studies insofar as possible. In almost all disciplines this will also involve certain basic descriptive studies. Such a program would require between 5 to 10 years to carry out fully, but could be divided into two or three phases.

It will be necessary to clearly define two specific research sectors, one at either entrance to the Strait. In order to limit the program to an area of manageable size it may be necessary to exclude much of Ungava Bay from the initial phase of the study. Because of the limited information presently available about the areas it will be necessary for the program to have a high degree of initial flexibility in order to adapt as our knowledge of the areas improves. The selection of specific monitoring stations, if required, may not be possible initially. A broad preliminary survey should be considered during the first two field seasons. This would involve sampling along a series of transects in the eastern and western Strait during different seasons. This would clearly require at least one large research vessel for several weeks. The possibility of also making use of ships of opportunity for certain aspects of the program should be investigated. Although large scale multidisciplinary efforts will be necessary to carry out much of the program, provision must also be made for working more intensively on a smaller scale for specific process studies. The repetitive sampling in a small area over extended periods is not economically viable using a large vessel. A smaller vessel based in the north, such as the one being constructed to replace the Calanus, could be used for carrying out such studies, particularly if it were operated in conjunction with a land based laboratory. A land based laboratory and helicopter support will be absolutely essential for field work during winter and spring as well as for certain localized long-term process studies carried out throughout the year. The use of helicopters will be essential for any seasonal studies, as ships can be used for sampling for only about 2-3 months in the year. Helicopter use will dramatically increase the cost of the project.

Current levels of DFO Quebec Region A-base funding for northern programs are clearly not adequate to support a research program of the magnitude and duration proposed. It is clear that substantial supplementary funding will be required. Some supplementary funding may be sought in relation to the impact of hydroelectric development impact and to aspects of fisheries development.

ESTABLISHMENT OF A PROGRAM COMMITTEE

The Steering Committee recommends that a Program Committee be established as soon as possible and be given the responsibility for developing a more detailed research program. The mandate of this committee would include the following:

1. To coordinate the development of a comprehensive research program based on the general recommendations of the Steering Committee outlined above. In other words, the program should be developed as a detailed analysis and comparison of the marine ecosystems present in the vicinity of the eastern and western entrances of Hudson Strait. It should be feasible to carry out the first phase of such a program within about 5 years given reasonable funding and other support. In developing the general program the committee

should consider the inclusion of studies relevant to the following sub-themes:

a) The management of harvestable stocks and an understanding of the trophic relationships of harvestable stocks.

b) The sensitivity of the marine ecosystem to hydroelectric developments in northern Quebec and downstream effects of changes in freshwater discharge into Hudson Bay. The hypothesis of SUTCLIFFE *et al.* (1983) relating Hudson Bay outflow, Hudson Strait mixing and east coast fisheries would be explored here and the Program Committee should consult with scientists from east coast laboratories regarding this.

c) The sensitivity of the ecosystem to climate change related to CO_2 buildup, particularly as mediated by changes in Hudson Bay outflow and changes in ice cover.

d) The sensitivity of the ecosystem to contaminants entering Hudson Bay.

2. To further develop a statement of justification for proceeding with the research program as a DFO priority.

3. To prepare a timetable for the program that identifies key deadlines in its development and implementation.

4. To develop a logistics plan that would adequately support the program. This would include recommendations about the size and location of any field stations and the type of vessel support required.

5. To recommend an approximate budget for the various components of the program. Capital items required would be identified and their costs listed.

6. To identify possible sources of funding for carrying out the research program.

7. To submit a draft report detailing the proposed research program within 6 months. This report will be circulated to members of the Steering Committee, researchers participating in the program, senior DFO management and interested client groups (Hydro Quebec, Makivik Corp. etc.) for their comments and suggestions. The objective is to have the program plan developed sufficiently so that it can be submitted as a work plan for initiation during fiscal year 1992-93.

The members of the Program Committee should be scientists who are likely to be actively involved in the proposed Hudson Strait research program. There should be at least one member of the committee representing each of the various disciplines that are likely to be involved. It is suggested that the committee consist of representatives from the following disciplines:

physical oceanography
chemical oceanography
biological oceanography
fisheries biology

marine mammalogy
marine ornithology
meteorology

A list of proposed names for these positions and for the chairman of the Program Committee will be submitted by the Steering Committee for approval by management. Members of the committee will be expected to consult as widely as possible with other researchers in their discipline who are interested in participating directly or indirectly in the research program in order to develop as comprehensive a program as possible.

REFERENCES

DUNBAR, M.J.1966. The seawaters surrounding the Québec-Labrador peninsula. **Cah. Geogr. Québec.** 19:13-35.

PETERSEN, G.H. & M.A. CURTIS. 1980. Differences in energy flow through major components of subarctic, temperate and tropical marine shelf ecosystems. **Dana** 1:53-64.

SUTCLIFFE, W.H. Jr., R.H. LOUCKS, K.F. DRINKWATER & A.R. COOTE. 1983. Nutrient flux onto the Labrador Shelf from Hudson Strait and its biological consequences. **Can. J. Fish. Aquat. Sci.** 40:1692-1701.

REPORTS OF

WORKING GROUPS

HUDSON STRAIT WORKSHOP

NOVEMBER 10, 1989

REPORT OF

PLANKTONIC AND ICE PRODUCTION

WORKING GROUP

CHAIR: L. Legendre

RAPPORTEUR: J.A. Runge

PARTICIPANTS: M. Bradstreet, J. Bunch, S. Demers, E.H. Grainger, S. Hsiao, G. Ingram, M. Poulin, J. Roff, C. Taggart, H. Welch

INTRODUCTION

The planktonic and ice productivity of Hudson Strait cannot be fully understood without a knowledge of the physical and chemical oceanography of the region as well. The present state of knowledge in all subject areas is rudimentary at best. Biological information gaps specifically mentioned during the working group discussion included: (1) the hydrodynamic control of primary production, in particular the role of tidal mixing and currents, (2) the fate of primary production and export pathways, (3) the pelagic food web, (4) the transfer of production to the benthos, and (4) hydrodynamics and biological production under the ice cover in the Strait. The research directions suggested below represent an attempt by the working group to synthesize the scant existing knowledge into testable and logistically feasible research objectives. These objectives are relevant to the long-term management of the Hudson Strait system, particularly for the management of pandalid shrimp and other potential fishery resources, for the conservation of food resources for birds and marine mammals, and for understanding the climatological significance of the region and the impact of climate change on the ecosystem.

RESEARCH DIRECTIONS

ICE ALGAL PRODUCTION

First-year ice typically occupies Hudson Strait and Ungava Bay between November and July. While ice-associated biological activity in this region has never been investigated, extrapolations from studies in other areas in the Arctic, including sites in Hudson Bay (HSIAO *et al.* 1984), Frobisher Bay (HSIAO 1980) and Resolute Passage (SMITH *et al.* 1988, CONOVER *et al.* 1986), predict the existence of a rich ice microalgal flora and an associated ice fauna. On the northwest coast of Hudson Bay at approximately the same latitude as Hudson Strait, WELCH & BERGMANN (1989) observed an ice algal biomass of up to 200 $mg \cdot m^{-2}$ in water less than 100m in depth. They found that ice algal biomass was a predictable function of overlying snow depth which effectively controls the light intensity reaching the bottom layers of the ice. This model also worked for data from the Resolute Passage region in Barrow Strait, although coefficients of the function were different due to differences in the light regime. Based on this knowledge, the working group formulated as a first hypothesis:

Hypothesis A1: Ice algal production in Hudson Strait is similar to production in northwestern Hudson Bay and follows the general model outlined in WELCH & BERGMANN (1989) that relates light and snow cover to ice algal growth.

The question was also raised in discussion about the relative contribution of ice algal production to total primary production. In the coastal Beaufort Sea, the quantity of carbon fixed each year by ice algae is thought to be small relative to the annual production in the water column (HORNER 1985), but arguably the contribution of ice algae could be much higher in Hudson Bay. This question takes on importance in the context of the role of arctic primary production in the global carbon cycle.

Because ice algae proliferate in early spring before the start of primary production in the water column, ice algal production may significantly enhance the productivity of arctic marine food webs by providing an early food source for sympagic (i.e. ice-associated), planktonic and benthic grazers (BRADSTREET & CROSS 1982). The working group discussed how ice algal production may be coupled to the pelagic and benthic food webs in Hudson Strait. In southeastern Hudson Bay, a significant fraction of the ice algal production was hypothesized to be retained in the pelagic environment. The dominant planktonic copepods (*Calanus* and *Pseudocalanus* species) were observed to graze on ice microalgae at the ice water interface and in the water column during and immediately after the ice algal bloom (e.g. RUNGE & INGRAM 1988). The total export of ice algae to the benthos (sinking cells and fecal pellets) was estimated to be ≈ 20 % (TREMBLAY *et al.* 1989). However, the linkage of the ice algal production to the pelagic food web in southeastern Hudson Bay may be the consequence of weak tidal currents in the area, which allows formation of microenvironments for ice algal growth, first at the ice-water interface and later at density interfaces in the water column. The Hudson Strait environment, on the other hand, is characterized by strong tidal mixing. Ice algae that slough off from the bottom ice may not remain at the ice water interface, but rather would be subject to scouring by tidal currents, similar to the situation in Resolute Passage (CONOVER *et al.* 1986, 1988), and to mixing in the water column. Consequently, the link with the pelagic food web in Hudson Strait may be weaker and most of the ice algal production may be exported directly to the benthos. The working group formulated the following hypothesis:

Hypothesis A2: Because of strong tidal mixing in Hudson Strait, the coupling between ice algal productivity and the marine food web is different than in Hudson Bay: most of the ice algal production in Hudson Strait goes to the benthos.

ZONES OF HIGH PRODUCTIVITY

The working group discussed the existing knowledge of the oceanography of Hudson Strait. Of particular interest were the indications of areas of high biological production at the eastern and western entrances to Hudson Strait. The evidence included reports of high diatom chlorophyll concentrations in eastern Hudson Strait (S. DEMERS, pers. comm.), high summer standing stocks of thick-billed murres in Ungava Bay and western Hudson Strait (GASTON, abstract, this proceedings) large concentrations of pandalid shrimp in the eastern end to the Strait (HUDON, abstract, this proceedings) and the seasonal abundance of seals and whales in the summer and winter, respectively (SMITH, abstract, this proceedings; Mitchell abstract, this proceedings). It is generally considered that there may be a relationship between these observations and the presence of deep tidally-mixed areas that occur at the entrances to the Strait, particularly in the eastern end (K. DRINKWATER, pers. comm.). The upwelling of nutrients associated with the tidal mixing may be fueling high primary production at the boundaries of the well-mixed areas. This primary production would support local benthic and pelagic food webs. Consideration of net transport of water in the eastern end of Hudson Strait suggests that there also may be an injection of nutrients and/or organic material into the Labrador current.

These preliminary observations and the ensuing discussion raised the following questions: (1) Are there areas of high primary production in Hudson Strait? (2) If so, why? (3) Is there a significant export of nutrients and organic matter onto the Labrador Shelf? (4) How would high primary production be coupled to local food webs leading to shrimp, marine birds and mammals? The most reasonable answers to these questions were formulated as a series of hypotheses:

Hypothesis B1: There are zones of high primary productivity at the eastern and western ends of Hudson Strait.

Hypothesis B2: These zones of high productivity are associated with deep tidally mixed areas.

Hypothesis B3: At the eastern entrance to Hudson Strait, there is export (injection) of nutrients and/or organic material onto the Labrador Shelf.

Hypothesis B4: Thick-billed Murres, pandalid shrimp, and possibly overwintering whales are spatially associated with, and feed in, the zones of high production.

FOOD WEB INTERACTIONS

It was recognized that the hypothesis B4 above is an incomplete response to the question about the coupling between production cycles and productivity of shrimp and other predators of human interest. The mechanisms by which primary production may be transferred via the food web to top predators must also be known in order to understand variability in the productivity of higher trophic levels. This requires a detailed understanding of the species composition of the food webs and an identification of the major interaction pathways (e.g DELAFONTAINE *et al.* in press).

A first step toward understanding food web interactions and their influence on top predator productivity is identification of predominant species in the system. PERCY (abstract, this proceedings) found evidence that the horizontal and vertical distribution of three species of pelagic amphipods of the genus *Themisto* in Hudson Strait differed considerably and appeared to be related to the interaction of the Atlantic and Arctic water masses within the Strait. It is likely that the distribution of other pelagic species in the region is also related to the presence of different water masses in the Strait. This implies that the species composition of pelagic food webs in different areas of the Strait will vary. In order to establish food web links to top predators like pandalid shrimp and thick-billed murres, the number and geographic extent of different food webs in the Hudson Strait region must be established. To start in this direction, the following hypothesis was proposed:

Hypothesis C1: Because of immigration of planktonic species due to advection and mixing of different water masses in Hudson Strait, there are gradients in species composition of plankton along and across the Strait.

The working group focussed on geographic differences in the pelagic food web. It is recognized, however, that differences in benthic species composition and the coupling between benthic and pelagic systems must also be considered.

LOGISTIC REQUIREMENTS

Logistic requirements were not considered in detail due to the limited discussion time. Testing of hypotheses presented above is considered to be technically feasible within a 5-10 year time frame. Sampling requirements for hypotheses B and C would involve cruises over several years to both ends of the Strait with a capability to survey the entire Strait. Testing of hypotheses on the role of ice algal production requires a sampling program on the ice in early spring before ice breakup with a minimum duration of three years. The desirability of establishing a fixed station in Hudson Strait for long-term monitoring of short-term variability was also put forward.

REFERENCES

BRADSTREET, M.S.W. & W.E. CROSS. 1982. Trophic relationships at high arctic ice edges. **Arctic**. 35:1-12.

CONOVER, R.J., A.W. HERMANN, S.J. PRINSENBERG, & L.R. HARRIS. 1986. Distribution and feeding by the copepod *Pseudocalanus* under fast ice during the arctic spring. **Science**. 232:1245-1247.

CONOVER, R.J., A.W. BEDO, A.W. HERMANN, H.J.H. HEAD, L.R. HARRIS, & L.R. HORNE. 1988. Never trust a copepod- some observations on their behavior in the Canadian arctic. **Bull. Mar. Sci.** 43:650-662.

DELAFONTAINE, Y., S. DEMERS, & J.A. RUNGE. Pelagic food web interactions and productivity in the Gulf of St. Lawrence: a perspective. **Can. Bull. Fish. Aquat. Sci.** (in press)

HORNER, R. 1985. Ecology of sea ice. Pp. 84-100 *In*: Horner R.A. (ed). **Sea ice biota**. CRC press, Boca Raton.

HSIAO, S. 1980. Quantitative composition, distribution, community structure and standing stock of sea ice microalagae. **Arctic**. 33:768-793

HSIAO, S. N. PINKEWYCZ, A.A. MOHAMMED & E.H. GRAINGER. 1984. Sea ice biota and under-ice plankton from southeastern Hudson Bay in 1983. **Can. Data Rep. Fish. Aquat. Sci.** 494. 49 pp.

RUNGE, J.A. & R.G. INGRAM. 1988. Underice grazing by planktonic, calanoid copepods in relations to a bloom of ice microalgae in southeastern Hudson Bay. **Limnol. Oceanogr.** 33:280-286.

SMITH, R.E. J. ANNING, R. CLEMENT, & G. COTA. 1988. Abundance and production of ice algae in Resolute Passage, Canadian Arctic. **Mar. Ecol. Prog. Ser.**: 48:251-263.

TREMBLAY, C., J.A. RUNGE, & L. LEGENDRE. 1989. Grazing and sedimentation of ice algae during and immediately after a bloom at the ice-water interface. **Mar. Ecol. Prog. Ser.** 56:291-300.

WELCH, H.E. & M.A. BERGMANN. 1989. Seasonal development of ice algae and its prediction from environmental factors near Resolute, N.W.T. **Can. J. Fish Aquat. Sci.** 46:1793-1804.

REPORT OF

FISH AND COMMERCIAL INVERTEBRATES

WORKING GROUP

CHAIR: G. Power

RAPPORTEUR: C. Hudon

PARTICIPANTS: M. Allard, F. Axelsen, R. Crawford, K. Drinkwater, S. Labonté D. McAllister, P. Richard, L. Roy, A. Sinclair, J.C. Therriault

INTRODUCTION

The marine resources of northern areas differ in several respects from those in more southern locations. Comparative research is particularly useful in providing insights into the contrasts between different environments. However, northern research is expensive and time consuming, which reinforces the need for well coordinated programs. There is also an acute need for the long-term planning of research and development programs in northern waters. The lack of winter data and the need for such information was pointed out, along with concerns about the costs and logistic feasibility of such studies.

Marine products originating in unpolluted northern waters are unique within the consumer market in North America and abroad. Their attractiveness may offset the higher costs of transport entailed in their distribution in the south.

LARGE SCALE OCEANOGRAPHIC PROCESSES

There is little information about the biological impacts on marine coastal communities of flow alteration following river damming, with the exception of the effects on local anadromous fish populations. The possibility was raised that flow alteration could have impacts that are more far ranging than the punctuated, short-term effects on local anadromous fish populations. It was felt that a large scale study should be carried out to investigate this question.

The National Workshop on Recruitment (1988) highlighted the influence of large scale physical oceanographic processes on recruitment of gadoid stocks in the northwest Atlantic, following the hypothesis of Sutcliffe *et al.* (1983). This hypothesis suggests that freshwater discharges into Hudson Bay influence mixing in Hudson Strait and the subsequent injection of nutrients into the Labrador Sea. Hydroelectric projects in the Hudson and James Bay areas and proposed large scale freshwater diversion projects (Grand Canal) would reduce the freshwater flow and regulate it seasonally, therefore, potentially altering the mixing process and the input of nutrient into the Labrador Current. The working group finds that a comprehensive study of the physical oceanography of Hudson Strait and its influence on the Labrador Current is justified.

The aspects that are potentially useful in a study of this kind would include:

1) a comparative study of historical satellite imagery, to determine the large scale, recurrent oceanographic features of the Strait;

2) a comprehensive analysis of the distribution of whales, pinnipeds and birds in the area, in order to use them as indicators of areas of concentration of food biomass;

3) modelling of the freshwater budget and flow from Hudson Bay to Hudson Strait to Labrador Sea.

MEDIUM SCALE PROCESSES

Hudson Strait has several distinct physical oceanographic characteristics such as:

1) intense mixing of Hudson Bay and Foxe Basin water at its western end;

2) a frontal zone across the entrance of Ungava Bay;

3) intrusion of deep Labrador Sea water and intense mixing at the eastern end.

There are also striking characteristics in the biogeography of the area. Fish and macroinvertebrate assemblages change along an east-west continuum through the Strait, from an arctic community in the west (northern Hudson Bay) to a subarctic-boreal community in the east (Labrador Sea). A commercially important population of striped shrimp (*Pandalus montagui*) is present at the eastern end of the Strait. This species is not found in comparable concentrations elsewhere in eastern Canada. Scattered populations of the Iceland scallop (*Chlamys islandica*) are found in Ungava Bay and Hudson Strait. Their presence could be related to the occurrence of fronts or other areas of intense mixing. Marine mammals populations (belugas, narwhal, walrus) also use Hudson Strait as a feeding area and migration route at certain times of the year. Important marine seabird colonies are found on Akpatok, Mansel and Digges Islands, and the birds extensively use local waters for feeding.

In addition to the need for basic studies on the biology and ecology of individual species (see reviews), studies of physical, chemical and biological interactions are needed to understand community structure.

The differences between the marine communities located at the eastern and western end of Hudson Strait should be studied in terms of the physical processes that drive them. The effects of major hydrographic features (fronts, gyres, etc.) should be perceptible:

1) on the biomass and production of the prey of scallop (phytoplankton) and shrimp (zooplankton).

2) on larval (scallop) and adult (shrimp) retention areas, with potential consequences on stock identification.

3) on the distribution and abundance of commercially important species.

The biological interactions and their differences along the Strait should be studied using:

1) a qualitative and quantitative (if possible) assessment of the food intake of marine mammals, to determine the potential impact of a commercial fishery competing with them for a particular prey species (e.g. beluga feeding on shrimp).

2) the predator-prey relationships between demersal fish (cod, turbot) and shrimp in eastern Hudson Strait.

3) the relative importance of the pelagic versus the benthic food webs as one moves from east (subarctic) to west (arctic) in the Strait.

4) the mechanisms of the transfer of pelagic production to the benthic filter feeders, and their importance in structuring benthic assemblages.

5) the factors limiting the abundance and distribution of fish of commercial importance in the Strait, and its possible importance as a nursery area for certain species of demersal fish (turbot).

SMALL SCALE COASTAL PROJECTS

Smaller scale coastal production systems are important to native subsistance fisheries. Changing technology in aquaculture may make raising scallops and mussels viable, in spite of the short duration of the growing season and the generally low temperatures. Exploration for scallop should be carried out in coastal areas using a lined dredge in order to collect small individuals and obtain information on the success of yearly recruitment. A study of the potential commercial exploitation of by-catch species should be explored, especially for species such as sea cucumbers and sea urchins. A study of the migration routes of anadromous fish could be undertaken, using telemetry, since they are likely to be influenced by the general circulation patterns in coastal areas.

LAND BASED STATION AND VESSEL SUPPORT

Although the group did not see a need for a fixed shore station for the study of commercially important species, it was felt that such a station would be useful for more detailed biological oceanographic studies. For instance, the study of the energy budget and use of bacteria and phytoplankton by scallops could be carried out on specific beds. This would also be conducive to a detailed study of the response of scallop populations to exploitation.

Substantial vessel support will be essential for carrying out any of the studies outlined above. A large vessel will be required for the medium scale projects, which will involve considerable ship time during the first few years (possibly even two ships during the first year). Smaller vessels could be used for many of the coastal and longer term studies.

INDICATORS OF GLOBAL CLIMATIC CHANGE

The Hudson Strait area is at the northern distribution limit of several species of commercial interest. Species whose distribution could be monitored include: Atlantic salmon, capelin, Atlantic cod off Killinek, as well as the growth pattern of mussels. Two types of indicators could be derived by 1) the monitoring of year-to-year variations in catches and 2) evaluating the year-class strength, as a result of variable recruitment. These indicators could in turn be related to various physical characteristic of the northern environment. Studies are presently being undertaken on various aspects of this problem, but more integration is needed.

REPORT OF

MARINE BIRDS AND MAMMALS

WORKING GROUP

CHAIR: A.W. Mansfield

RAPPORTEUR: R.R. Reeves

PARTICIPANTS: E.G. Atkinson, J. Boulva, A. Gaston, J. Green, P. Larouche, D. Mudry, J. Percy, T.G. Smith

INTRODUCTION

The populations of marine mammals and marine birds in Hudson Strait represent a major resource. Most of the populations are migratory, moving into the Strait in winter (whales) or summer (birds and seals). In order to help the working group focus its discussions, the major populations using Hudson Strait were ranked according to their relative importance to native harvesters, times of year when present in the Strait and conservation status (Table 1).

The working group was divided on the question of whether research planning should emphasize an ecosystem or a species/population approach. Obviously, the scientific payoffs of multidisciplinary, holistic, ecosystem approaches are high. In a long-term view, management may require that such things as energy flows, ice dynamics and population parameters be integrated and understood within the same framework of analysis. However, there are practical impediments to implementing such an approach. Marine mammals and, to a lesser degree, birds have a high profile economically and politically. Their importance in the cultural life and nutrition of native communities is high, and non-northerners take a great interest in their protection or conservation. As a result, there is always pressure on DFO (and CWS) to study and report on these organisms species by species. Another practical obstacle to interdisciplinary work is sampling scale. Whereas an oceanographer may find it necessary to establish fixed sampling sites in a well-defined area, anyone attempting to study marine mammals is faced with sampling the animals' life-processes and behaviour over a very large and often unpredictable area. The mobility of marine mammals makes it difficult to fit them into any localized ecosystem study. Colony-nesting birds are probably more amenable to such approaches although they, too, can be extremely mobile, even during the nesting season.

There is also a time-scale difference between research on invertebrates and fish, for example, as opposed to marine mammals. Year-to-year oceanographic changes often have dramatic effects on stocks of invertebrates and fish, and these effects can only be studied by reference to basic physical processes. The long-lived marine mammals appear to be less sensitive to such changes, although large-scale population fluctuations are known to occur (e.g., ringed seals in the Beaufort Sea during the 1970s), presumably linked to ecosystem changes whose ultimate causes are physical.

Table 1. Marine mammal stocks in Hudson Strait arranged in order of importance to native harvesters.

Species	Presence in Strait: Winter	Summer	Status
Beluga	+	@	A, D, E *
Walrus	+	+	D
Ringed seal	+	+	A
Bearded seal	+	+	A
Harp seal	-	+	A
Polar bear	+	-	R
Narwhal	+	-	R
Bowhead	+	-	E
Harbour seal	-	+	R
Minke whale	-	+	R

+ = present A = Abundant R = Rare

- = absent D = Declining

@ = comparatively few E = Endangered

* The 3 beluga stocks are: A - Western Hudson Bay; D - Eastern Hudson Bay; E - Ungava Bay.

Insofar as it is possible, managers should be encouraged to treat studies which promise to contribute to an understanding of entire ecosystems as a priority. The importance of projects which involve long-term monitoring of various physical processes was emphasized. Although the potential applications of such projects may not be immediately obvious, the data collected are likely to become increasingly valuable in tracking and analyzing biotic trends in the future.

MARINE MAMMALS

Because of the influx of belugas, bowheads and possibly narwhals into Hudson Strait in winter, it is essential that marine mammal fieldwork in the Strait be undertaken at that season, rather than only during the summer. This requirement presents great challenges, since these animals are difficult enough to study in summer open-water conditions. The population of belugas in the Strait during winter is apparently large and dispersed over a wide area. To enumerate them would require extensive aerial surveys combined with observations made from the ice ("ground truthing"). Gaston pointed out that he had some success in using ice reconnaissance aircraft from the Atmospheric Environment Service of Environment Canada as platforms-of-opportunity for marine bird surveys. It was suggested that mammal surveys in winter and spring might be made from these same aircraft.

BELUGAS

Belugas are important in at least three respects: a) there is a high demand for their utilization by native communities, b) there is much international, national and regional interest in their conservation, and c) their large numbers and high aggregate biomass mean that they play a significant role in the trophic dynamics of their environment. The critically low level of the Ungava Bay summer population requires a continuing need for stock assessment and stock identification work as well as effort to educate and communicate with the public about the results of such work. The subsistence catch in Ungava Bay and Hudson Strait needs to be sampled for tissues to use in DNA analyses aimed at stock identification. Since the belugas of Hudson Bay appear to spend a least six months in or near Hudson Strait, their activities there deserve close study. Breeding and feeding probably take place in the Strait, but little direct evidence is available for either. It was suggested that the different stocks of belugas using the Strait in winter may have distinct distributions, an idea that might be evaluated with data from systematic winter overflights, preferably complemented with detailed sampling from the ice during the survey period.

WALRUSES

There is no good information on population size and stock identification. Although the use of walruses by communities in northern Quebec appears to have declined because of the limited need for dogfood at present and because of a continuing trichinosis problem, concern remains particularly about the walruses on the Ottawa and Sleeper islands which are hunted by people from Povungnituk as well as from the Belcher Islands. Walrus stock identities could be studied through DNA analyses as well as through satellite tracking; methods for both are in an advanced state of development.

Walrus haulout sites, like bird nesting colonies, offer possibilities for collaborative work among scientists working on different groups of organisms as well as different aspects of the ecosystem. A proper benthic survey needs to be done in the vicinity of one or more walrus haulout sites, along with observational studies of the walrus at the site and studies of the oceanographic features which shape and sustain the benthic community there.

RINGED SEALS

McLaren's work on ringed seals in northwestern Hudson Strait resulted in his hypothesis concerning the relationship between coastline complexity and seal production. Little is known about ringed seal populations and production elsewhere in the Strait and in Ungava Bay. Ice maps of Ungava Bay suggest that there is relatively little suitable fast-ice habitat for ringed seals, but there could be some production in the pack ice.

HARP SEALS

At present, harp seals are probably the most abundant marine mammals in Hudson Strait during summer. It is uncertain whether this is a new phenomenon or simply one which had not been recognized previously. The Inuit at Salluit do not eat harp seal meat. If this lack of interest in these seals is more general, then it should not be surprising that large numbers of harp seals do not appear in catch records from settlements in the Strait, particularly since they are among the most difficult seals to hunt. Gaston noted that his group working at Digges Island since 1979 had not observed large numbers of harp seals. Since the harp seal population in the Northwest Atlantic is thought to be growing rapidly following the collapse of the sealing industry it seems likely that the perceived change in their use of Hudson Strait is real.

POLAR BEARS

Polar bears may play an important role in the ecology of Hudson Strait marine mammals. For example, the large numbers of bears in northern Hudson Bay may prey heavily on ringed seals dispersing southward and westward from the highly productive pupping grounds off southwestern Baffin Island. Akpatok Island in Ungava Bay is also said to be a good place for polar bears, but what this suggests about the availability of potential prey is unclear. It is known that some polar bears specialize in capturing belugas and that considerable predation may occur in Hudson Strait in winter when the whales are confined to narrow leads. Other bears appear to spend considerable time near walrus haulout sites, possibly indicating that they depend on young walruses as prey.

MARINE BIRDS

A high proportion of the seabird biomass in Hudson Strait is in the form of thick-billed murres. Recent work has focused mainly on the ecology and population dynamics of this species at Digges and Coats islands. There is much interest among CWS scientists in undertaking collaborative work with oceanographers and marine biologists working on other aspects of the environment. To take their murre studies further, Gaston and his colleagues need input from people studying other trophic levels. An interesting point which arose during the Working Group's discussion was the similarity in life-history parameters and possibly food requirements between thick-billed murres and ringed seals.

Among the areas to be addressed in future studies of marine birds in Hudson Strait are:

a) the nature and magnitude of the autumn (September/October) influx of birds into the Strait (virtually nothing is known about this at present),

b) bird distributions generally in the non-breeding season,

c) ecology of common eiders along the north shore of the Strait and in Ungava Bay,

d) monitoring of puffin numbers as an index of capelin abundance.

As with walruses, eiders are expected to have interesting but, so far, poorly documented effects on benthic invertebrates in the shallow waters (mainly less than 10m) where they feed.

ARCTIC COD

The arctic cod, *Boreogadus saida*, was identified as a key organism for both birds and marine mammals in Hudson Strait. It is a principal prey of belugas, narwhals and harp seals. It was noted that very little is known about the population dynamics and ecology of arctic cod. Unfortunately there are severe sampling problems to be overcome in attempting to study the species.

RESEARCH FACILITIES

A permanent station at a single site would encourage interactions for interdisciplinary studies, since researchers from different disciplines inevitably meet one another while in the field. Much of the marine mammal work, however, may require a site for little more than ship support since most laboratory facilities will be on board and the animals under study are highly mobile.

The Working Group agreed that Ivujivik has much to recommend it as a location for a permanent research facility, including:

a) a varied coastline, with cliffs, fiords and shallow flats, and fast ice stretching all the way to the Nuvuk Islands in winter,

b) the CWS work carried out on nearby Digges Island which provides a valuable, information base which might prove useful to other types of study,

c) its strategic position for studying birds at the islands, whale migrations to and from Hudson Bay and water/energy flows between Hudson Bay and Hudson Strait.

One drawback is that there is no accommodation at Ivujivik at present.

Two other sites were discussed. Deception Bay with its airstrip at Asbestos Hill, was considered to be of low potential because of its remoteness and lack of facilities. The abandoned Coast Guard station on the south coast of Nottingham Island offers a good anchorage and many buildings but no airstrip.

Since the island is near the middle of the Strait, it might be appropriate for the Central and Arctic and the Quebec regions of DFO to share maintenance costs.

Gaston pointed out that the CWS in Ottawa is equipped to serve as a long-term tissue bank for biological specimens. He urged that consideration be given to ensuring that tissues from mammals collected in Hudson Strait and elsewhere in the arctic and subarctic be stored in a facility with suitable back-up power.

REPORT OF

RESOURCE MANAGEMENT AND ENVIRONMENTAL IMPACTS

WORKING GROUP

CHAIR: R. Clarke

RAPPORTEUR: G. Chantigny

PARTICIPANTS: M. Breton, B. Campbell, G. Chapdelaine, M. Dunbar, R. Harland, J. Lovrity, E. Mitchell, R. Morin, D. Nakashima, D. Pike, D. Ponton

INTRODUCTION

The chairman welcomed the group, stressed the importance of the workshop and urged the group to focus mainly on resource management and environmental impacts during the discussion. A tabulation of the existing knowledge and major gaps identified during the previous day's presentations was used as a basis for discussion (Table 2).

The following general remarks were made during the preliminary discussion of current knowledge and information gaps:

- The objective of the present exercise is to bring together in a presentable, understandable, logical and chronological background report all work in Hudson Strait and other relevant water bodies during the last 10 years.

- We should try to make comparisons with other similar arctic areas (e.g. Greenland) and if possible apply existing knowledge about them to Hudson Strait.

- We should consider using seabirds as early indicators of environmental changes.

- We should try to identify and define the information gaps as soon as possible.

- We should try to identify key areas for specific research programs.

- We should attempt to develop both short and long term hypotheses.

- In order to develop research relevant to management problems we need to know the pertinent habitat legislation and policies.

- We should recognize that changes to the habitat could occur without necessarily changing its productivity.

Table 2. A summary of significant information gaps relevant to marine resource management and habitat protection in the Hudson Strait region.

KNOWLEDGE	GAPS
	OCEANOGRAPHY
1st order physical oceanography	-Melt water fate -Nutrient fluxes -Confirm mixing areas -Nutrients/Contaminants -Transport/Variability -Winter conditions
	FOOD CHAIN
Models from non Hudson Strait sources. Some information on feeding relationships.	-Confirm models -Magnitude and nature of productivity -Feeding, energy flow etc. -Importance of different water masses
	MARINE MAMMALS, BIRDS, FISH AND INVERTEBRATES
Occurance of some species	-Biology and distribution of fish. -Abundance of harvested species of fish. -Presence of other fisheries resources. -Temporal variations in distribution and abundance. -Arctic charr/seabirds - importance in marine areas. -Impacts of shrimp fishing on beluga. -Walrus abundance. -Beluga stock identity. -Beluga and walrus decline. -Seabird food webs and prey distribution.
	HABITAT
Contaminants (Hg, PCB, etc.)	-Standard surveys; source, transport, fate, biological effects.
Hydro electric power and water diversions	-The effects on Hudson Strait ecosystem and resources.
CO2 increase Ozone depletion	-Long-term implications for arctic marine habitats and wildlife.
No net loss	-Application of no net loss.

- Eastern and western Hudson Strait should be given priority. This would give us a good basis for developing an understanding of the entire Hudson Strait area.

- Consideration should be given to initiating a long term, year-round, monitoring program involving local people as monitors responsible for collecting basic information.

- Native environmental knowledge should be incorporated, where possible, into arctic biological studies. Discussions about gaps in scientific knowledge repeatedly emphasized the absence of basic environmental information. A first step in any research program designed to address resource management or impact assessment needs is the identification of what there is, not necessarily how many, but at least the basic distributions and associations of species present. Long-term monitoring of the environment may also offer important insights into the possible consequences of climatic changes. One source of valuable information pertaining to both these questions, that has largely been neglected by the scientific community, is the ecological knowledge of native residents.

A variety of research requirements were discussed by the working group.

Following these dicussions a number of research projects were proposed as components of larger general themes. The main themes were as follows:

i) assessment and prediction of biological resources and productivity.
ii) basic understanding of Hudson Strait.
iii) long-term monitoring.
iv) population assessment.
v) marine mammals
vi) hydro development impact
vii) contaminants.

The group divided into small groups of one or two individuals to develop proposals on each of these themes which would include the following points:

- Problem statement
- Objectives
- Geographical area
- Time frame
- Interdisciplinary linkages
- Vessel/Laboratory/Field needs
- Priority

PROPOSED RESEARCH PROJECTS

1. ASSESSMENT AND PREDICTION OF BIOLOGICAL RESOURCES AND PRODUCTIVITY

A. Alpha-level descriptions/documentation/inventory

a) discover, name, describe species; map their occurrences and distribution

b) deposit voucher specimens in museums/repositories

B. Ecological context

a) characterize habitat (including climate)

b) document variability

c) characterize contaminants, other perturbations and their pathways

C. Long-term monitoring

a) baseline studies

b) repetitive sampling

c) sampling of biological populations at appropriate intervals (from 5 to 20 years for some marine mammal populations)

d) modelling response of population to natural and man made perturbations

i. target studies to define stock identities
ii. document direct and indirect removals from defined populations; also estimate loss rate in fisheries
iii. document biological parameters through collection of biological samples and data
iv. model population dynamics
v. input environmental parameters
vi. input removals; model response of population to exploitation

2. UNDERSTANDING THE ECOSYSTEM OF HUDSON STRAIT FOR RESOURCE AND HABITAT MANAGEMENT.

Problem statement:

Understanding the stucture and functioning of the Hudson Strait ecosystem is essential for proper resource management and habitat protection. Little specific knowledge exists at present. The area is influenced by events occurring outside of Hudson Strait. Activities on nearby land areas can also affect habitat and resource management in Hudson Strait.

Objectives:

There are several interrelated objectives:
- identification of microorganisms, fish, invertebrates, marine mammals, plants and birds and where they belong in the food chain.
- understanding of productivity and factors controlling it, throughout the ecosystem, especially for the harvested species.
- identifying and characterizing areas of importance for productivity and key stages of organism life-cycles.

Area of operation:

- priority areas are the Eastern and Western ends of Hudson Strait and surrounding areas.
- should include coastal and offshore areas for resource management.
- habitats and resources in coastal and estuarine areas.

Time frame:

- immediate start
- include winter

Interdisciplinary linkages:

- Interdisciplinary research on Hudson Strait, should include physical and chemical oceanography, productivity, fish, invertebrates, marine mammals, plants and birds.
- support from, and discussions with, native and other groups (university, hydro electric companies, etc.).

Support requirements:

- vessel and field laboratory needed.
- experts should design overall programs in consultation with renewable resource and habitat managers.

Priority: high

Without this information, the management of habitat and fisheries resources will be based on unproven theories and speculation.

3. MONITORING: CONTAMINANTS AND CLIMATE CHANGES

Problem statement:

It is important to monitor any environmental changes that are likely to have significant future impacts on ecosystem structure or function.

Objective:

To obtain long term **TIME SERIES** observations of such things as:

- temperature and salinity changes in the sea.
- air temperature changes (already being supplied by AES).
- river outflow variations.
- pollutant concentrations in environment.
- changes in selected populations of organisms.
- changes in pollutant concentrations within organisms (i.e. setting up a tissue bank).

Geographic area: Hudson Strait and vicinity.

Time frame:

- Continuing indefinitely if it is to produce time series of adequate value.
  a) once a year for most parameters to be measured.
  b) at least twice a year for climatic variables.

Interdisciplinary linkages:

- biogeography (spatial distribution).
- pollution control.
- food web research.
- general ecosystem considerations.
- resource harvesting.

Vessel/Lab/Field needs:

1. For oceanographic measurements: a ship and two hydrographic stations, one at each end of the Strait, occupied once or twice a year.

2. A laboratory either on board ship or on land.

Priority: High

4. POPULATION ASSESSMENTS

Problem statement;

a) management of a utilized or potential resource requires knowledge of stock size and factors affecting stock size. This is essential for the establishment of safe harvesting levels.
b) fluctuation in population of organisms may be indicative of progressive environmental changes.

Objectives;

a) to determine the distribution and abundance of various species inhabiting Hudson Strait (include seasonal changes in abundance - e.g. migration of beluga whales).

b) to determine critical factors which affect species distribution and abundance (e.g. pattern in natural mortality, prey abundance, disruption of migratory pathways).
c) to continue monitoring some target populations over long period of time.

Time frame; varies depending on species being assessed
a) marine mammals: survey can generally be done over short period if methods are available. However method development may take many years. Studies should be repeated on decade scale in order to detect changes.
b) fish and benthos: survey may take short time, but methods may not be available - should be repeated on a 2 to 5 year scale.

Interdisciplinary linkages;
a) development of proper survey methods requires integration of virtually all behavioral and ecological knowledge of the species.
b) surveys for different species should, if possible, be geographically integrated so that interspecies interactions can be assessed - e.g. idea of development of a standard sampling grid for Hudson Strait may have some validity.

Vessel/Lab/Field needs;
a) marine mammals studies require vessel, aircraft and limited laboratory space.
b) fish and benthos studies generally need extensive vessel use and some laboratory space.

Priority; high

5. MANAGEMENT OF MARINE MAMMALS

Problem statement;

Lack of adequate information to estimate sustainable harvest levels for marine mammals. Specific problem areas being:

beluga
- need mortality information: natural and harvesting.
- stock discreteness: clarification essential for management.
- declines: if no stock discreteness there is no overall decline, if stock are discrete - e.g. Ungava Bay, Eastmain, Cumberland Sound,- then decline is due to overfishing.
- need to know energetics to determine interactions with food base and possible effects of harvest of species in resource base.
- management must consider other users - i.e. Baffin/Greenland residents.
- critical habitat.

narwhal
- same as for beluga.
- population surveys every 5 years.

walrus
- need to know population abundance.
- distribution.
- stock identification.
- interaction with resource base.
- why range is declining

harp seal - abundance and distribution in Hudson Strait.
- interactions with food base.
- possible future harvesting.

bearded seal - abundance and distribution.
- interaction with food base.

Objectives:

To undertake the necessary research to obtain information for development of population models by DFO to permit the implementation of harvest regulation based on biological constraints by 1995.

Geographical area: Davis Strait, Hudson Strait, Hudson Bay and James Bay

Time frame: starting immediately and continuous

Interdisciplinary linkages:

- archival and anecdotal information to provide historic perspective.
- voucher specimen/tissue banks etc.
- physical/chemical/biological oceanographic information: past, present and predictions for future.
- fisheries resource assessments to link food base interactions.
- other DFO regions.
- lobbyist and political impacts.
- climatic changes.

Vessel/Lab/Field needs:

- dedicated vessel to undertake multi-disciplinary research
- dedicated aircraft
- multi-disciplinary facility in Hudson Strait area to adequately handle and preserve sensitive tissue collections on site.
- supply system for field stations

Priority: medium high to high

6. HYDRO POWER/WATER DIVERSIONS/RUN OFF

Problem statement:

Hydro electric developments may result in a number of effects on biotic and abiotic processes on both small and large spatial scales. On a small spatial scale, there is an immediate risk of the loss of habitat for exploitable fish resources. At the same scale, the impoundment of large fluvial water masses, reduces the flow of particulate organic matter to the coastal zone and potentially results in changes to trophic processes. Changes to the physical regime result in a loss of primary production by marine ice algae. On a larger spatial scale, it has been hypothesized that year-to-year variations in freshwater discharges into Hudson Bay affect the degree of mixing in Hudson Strait, subsequently affecting recruitement of fish stocks in Hudson Strait and the Labrador Shelf. The seasonal regulation of flow in impounded rivers will impinge on this process, possibly reducing dynamic physical processes in Hudson Strait, with unknown ecological consequences.

Objectives;

a) improve our understanding of physical processes within Hudson Strait in order to evaluate the role of seasonal and year-to-year variations in run-off.

b) further evaluate the hypothesis proposed by Sutcliffe *et al.* (1983) concerning the influence of run-off on mixing in Hudson Strait by incorporating data obtained since the development of the La Grande complex. Does this phenomenon exist? If so, how important is it ecologically?

c) conduct studies that evaluate the role of terrestrial organic inputs to the marine environment and to coastal production.

Geographical area:

a) large scale implications for east and west Hudson Strait

b) Hudson Bay and Strait for salmon and Labrador coast for marine fish recruitment

Interdisciplinary linkages: physical, biological oceanography and fish biology

Time frame: Immediately and continuous

Priority: high

7. CONTAMINANT: SOURCES, PATHWAYS AND FATES

Problem statement:

a) identify relevent contaminants such as PCB'S, hydrocarbons, trace metals and radioactivity.

b) identify their sources, such as atmosphere, hydro sites, settlements, mining or ship traffic.

c) identify their transportation routes through atmosphere, water currents and various food chains.

Objective: to provide resource managers with baseline values and critical levels.

Geographical area:

Hudson Bay and Strait, especially close to settlements, hydro sites, mining sites and stations in east and west of Strait.

Interdisciplinary linkages:

a) combine chemical & physical oceanography.

b) collections by biologists (fish, mammals, birds etc.).

c) analysis; both a field and a southern laboratory with standard analysis procedures to which all samples may be forwarded. Samples could also be collected at various settlements by local residents.

Time frame: immediate and continuous

Vessel/Lab/Field needs:
a) vessel necessary for collection of specimens.
b) field lab required for some immediate analyses.

Priority:
Medium high, depending on hydro projects.

REPORT OF

FINAL PLENARY SESSION:

CHAIR: M.J. Dunbar

RAPPORTEUR: C.T. Taggart

INTRODUCTION

The following is a compilation of the plenary discussions that followed the presentation of the summary reports by each of the working groups. I have tried to preserve the essence of the discussions in a generally chronological order. However, several topics were returned to on different occasions during the session so I have taken the liberty of occasionally ignoring the chronology and grouping related ideas. I have also attempted to enhance the presentation by citing examples or by suggesting approaches that might be considered in future planning.

The chair expressed some concern about the "shopping list" attitude that developed and also about the escalating costs associated with the research ideas that proliferated during the workshop. He then summarized his thoughts about what had been presented, and did so under several headings that were neither all inclusive nor in any particular order of priority. These topics provided a useful framework for organizing the subsequent discussion. There was not sufficient time, however, to discuss all of them at length.

PHYSICAL OCEANOGRAPHY

Drinkwater's presentation on the physical oceanography of the Hudson Strait region was considered a relevant and useful background to the remainder of the workshop, particularly by presenting the hypothesis of Sutcliffe *et al.* as an example of one type of approach that should be considered in the development of a Hudson Strait research program.

OCEANOGRAPHY AND CLIMATE

Oceanography and climate change was briefly examined and in particular the question of how a Hudson Strait study would be relevant to currently evolving concerns. Although the effect of CO_2 increases in the atmosphere remains unclear (research in Greenland was cited as an example) the subject of the importance of long-term monitoring, particularly in arctic and subarctic regions was raised.

It is worth noting that along with the Hudson Strait workshop several international programs in climate and fisheries have been evolving: GLOBEC (USA primarily), and CACC (cod and climate changes in the north Atlantic) involving Canada, Denmark, the Faroes, France, Iceland, Netherlands, Norway, UK, USA, USSR and presumably integrated in some way or another with ICES, SCOR, IOC, ACCP, and OPEN etc. These programs and other relevant ones such as the NORTHWATER project should be kept in mind during planning, and organizers of these programs should be notified of developments related to a Hudson Strait research initiative.

With global climate change in mind, Legendre noted the prevalence of first year ice in the Hudson Strait region, in contrast to the arctic region as a whole, where multiyear ice predominates. The annual melting is of importance to many oceanographic and ecological processes and must be carefully considered when selecting variables for measuring and locations for monitoring.

MONITORING

The question of whether marine monitoring was necessary or not was addressed at some length. The IBP programme was cited in this context. Two distinct views were expressed, one strongly in favor of long-term monitoring and the other opposed, largely because of the competition for limited funds with other, perhaps more immediately relevant, shorter-term programs. It was suggested that if a Hudson Strait research program did go ahead, then two sampling stations, one at either end of the Strait could be used for monitoring a variety of relevant variables, such as temperature, salinity, chlorophyll, plankton biomass, etc. This would allow for both hindcasting: using old data series to address questions, as well as forecasting: making predictions about oceanographic change. Such a long-term, continuous data set would be of considerable value, although the cost could be significant. It was emphasized that any research relevant to the question of climate change would of necessity involve long-term monitoring. Dunbar noted that it was only because of long-term monitoring projects that the Greenland cod populations were discovered in 1917.

It was emphasized that an annual research program must extend through the winter months. This is not a new idea, but winter work has generally been neglected because of the the high costs, and the difficult logistic and technical problems. It was stressed that our knowledge of "winter" processes is orders of magnitude less than that of comparable "summer" processes in temperate, subarctic and arctic seas. This "seasonal" ignorance may have important consequences on our ability to predict oceanographic, biological and climatic processes.

The establishment of land-based laboratories must be considered carefully as they are often under-used, particularly as the specific research programs for which they are intended are completed. They are also of less relevance if suitable ships are readily and reliably available. The availability of suitable ships, particularly ones capable of operating in ice, is crucial to future arctic research in Canada. Questions about the status of the proposed POLAR-8 icebreaker were raised by Taggart. Was it going to be built? If so, when? Would it be designed to accommodate scientific oceanographic research? Dunbar understood that no scientific capacity was being considered. Clarke and Crawford stated, however, that scientific needs had been considered in the planning of the vessel. It is clear that the availability of a suitably equipped ice-going vessel similar to the POLAR-8 will be essential to the future development of arctic marine research programs in general and a Hudson Strait program in particular.

Ingram again raised the question of where monitoring should be carried out. Dunbar suggested that oceanographic sections at the eastern and western ends of Hudson Strait would be important, based on the workshop presentations and discussions. Drinkwater emphasized that the selection of stations must be done carefully and after thorough analysis of existing data. Drinkwater also expressed concern about possible aliasing[3] problems, particularly with existing data. These may lead to false conclusions and result in the selection of the wrong sampling frequency at any designated sites. Aliasing has caused considerable problems in many oceanographic studies and it is essential not to ignore its effects, particularly in the Hudson Strait region where large tidal excursions are associated with large and possibly sharp spatial and temporal gradients. Dunbar mentioned that the Danes faced this problem in their monitoring studies in Greenland and that their database and experiences may prove useful. Drinkwater agreed, but again stressed extreme caution in planning.

Gaston noted that fixed (land-based) stations tend to promote long-term monitoring even in the absence of other ongoing research programs. Furthermore, they tend to foster multidisciplinary research, because of the close and frequent interactions of the various users. Percy noted that the land-based laboratory concept can be made more flexible if the so called "permanent" station is, in fact, a relatively "portable" one consisting of properly equipped trailers. Taggart suggested that consideration might be given to using a suitably outfitted barge for carrying out both monitoring and specific research programs. The advantage of such an approach is that it allows for greater portability than a land station, and a longer-term fixed-position capability than is possible with a ship. Welch considered this a valid approach but expressed concern about winter ice conditions and the associated problems that a fixed barge would encounter. Having it fixed in ice and drifting might be used to advantage (e.g the "ice-island" approach) under some circumstances.

It was clear that monitoring of the environment and biota must be an important component of any future research program in the Arctic, but it must be clearly recognized that this implies a long-term commitment.

TISSUE BANKS

Given the current concerns about the concentrations of contaminants in the environment and their transport over great distances and the developing population genetic technology, it was felt that serious consideration should be given to establishing a tissue bank of samples from northern species a soon as possible. This could be done relatively inexpensively by coordinating existing sampling programs, and its long-term value would far outweigh the initial costs. Such a collection would ensure the acquisition and safekeeping of baseline data and would allow the analysis of a variety of contaminants when specific, but as yet unanticipated, problems arise in the future. The evidence to date indicates that contaminant problems will continue to occur with increasing frequency.

---

[3]Aliasing - introduction of error into the computed amplitudes of the lower frequencies in a Fourier analysis of a function carried out using discrete time samplings whose interval does not allow the proper analysis of the higher frequencies present in the analysed function [Dictionary of Scientific and Technical Terms, 4th ed. 1989. McGraw-Hill, N.Y.]. Creating or destroying cyclic patterns in data because the sampling frequency was too low [C.T. Taggart].

ICE BIOTA

Sea-ice and the under-ice biota were identified as topics that need more research. There appears to be a significant trophic link between the primary producers (ice algae), the secondary producers (zooplankton predators on the ice algae), and tertiary producers such as arctic cod and the warm-blooded vertebrates. There is, in addition, some evidence that the general patterns of ecosystem energy flow vary in different climatic zones. In the tropics a significant proportion of primary production is used within the pelagic zone, whereas in arctic and subarctic regions more of the production may be cycled through the benthos. If this phenomenon is indeed related to latitudinal climatic gradients then current concerns about the changing climate are of considerable relevance.

INDICATOR SPECIES

From a large scale, long-term perspective it was suggested that consideration should be given to the study of selected indicator species such as capelin, various copepod species or species of hyperiid amphipods, which show distinct latitudinal, temperature, and water mass preferences in their geographic distribution and origin. Identifying their distributions could be useful in monitoring climatic change and related large scale variations in the ocean environment. Dunbar pointed out that historical records certainly seem to reflect this and Gaston referred to data that suggests large scale "roaming" of certain species. The potential utility of suitable indicator species in environmental impact and climate change studies should not be ignored.

LEADS and POLYNAS

Leads and polynas have only received relatively superficial study to date. However, there is growing evidence that these relatively small ice-free regions may be responsible for large oceanic and atmospheric heat transfers and may, in addition, play an important role in the overall productivity of arctic regions. Several Canadian arctic researchers are presently developing a comprehensive program to study the oceanography and biology of the northwater polynya in Northern Baffin Bay (Northwater proposal).

MARINE MAMMALS

Percy noted that the potential impacts on the ecosystem of increasing harp seal populations summering in Hudson Strait and elsewhere had not yet been addressed. This increase is largely a consequence of the curtailment of the commercial hunt in the Gulf of St. Lawrence and the Newfoundland front and the subsequent expansion of the animal's range. Mansfield noted that the productivity of the stock is very great. A substantial increase in their population in the Hudson Strait region would probably have a measurable impact on the other marine resources of the region. However, the exact nature and magnitude of the anticipated impact is uncertain because of the scant information about their diet in the region. Richard noted that harp seals are now regularly observed as far west in the region as Repulse Bay and Hall Beach on Melville Peninsula.

INTERNATIONAL COLLABORATION

Given the present scarcity of suitably situated land-based laboratory facilities and the limited availability of suitable research vessels it was suggested that international co-operation and joint programs be seriously considered. The Soviets in particular appear to be increasingly amenable to joint research programs in the Arctic. In addition, American researchers frequently invite Canadian participation in their northern programs, but Dunbar was of the opinion that "we" don't often do likewise. Dunbar pointedly stated that if "we" are recognized as "leaders" in arctic marine research then we should "open up" to international co-operative efforts in this area.

INUIT INTERESTS

Power noted that items of specific interest to northern residents had not been adequately addressed during the workshop. He specifically cited the possibilities of environmental effects on the recruitment of various species of importance to the Inuit. Dunbar also emphasized that the interests of the Inuit populations of the Hudson Strait region must be carefully considered during the development of a marine research program to be carried out in the area.

WHY HUDSON STRAIT?

In response to Boulva's question "Why Hudson Strait ?", instead of Hudson Bay for example, Dunbar argued that it was primarily a matter of the time and space scales under consideration, as well as the inflow and outflow to and from the region and the greater inherent variability of the system. Roff pointed out several distinctive features of Hudson Strait: first-year ice, relatively high production, large marine mammal and bird populations, and exploitable fish, shrimp and scallop stocks. Dunbar further added that the "energy in - energy out" concept is particularly amenable to the Hudson Strait region. Mitchell raised the "nexus" problem (see abstract MITCHELL & REEVES, this volume) in that the available data on the great whales in the area are not consistent with the idea of a highly productive region. However, it was pointed out that 10,00-12,000 belugas, and possibly the bulk of the Hudson Bay stock move into Hudson Strait to over-winter and feed. This was seen as significant given that they could move to other areas of unconsolidated pack, such as in Davis Strait. If they are feeding during this time then there must be a high standing crop of prey to support such a large population. Historical data show that various other whale species were once abundant in the region during the summer.

Taggart asked if the historical distributions of the Inuit populations provide any insights into the distribution of marine productivity in the region. Dunbar suggested that this would be so, although Clarke warned of the distorting effects of recent cultural and social changes. Richard noted that approximately 2/3 of the Eastern Arctic Inuit population now resides in the Hudson Strait - Hudson Bay area and that years ago many more were moved from the Hudson Strait region and resettled elsewhere as a result of political decisions.

Welch noted that Hudson Strait shares a number of distinctive similarities (particularly pertaining to physical oceanography) with the more southerly Gulf of St. Lawrence and with the more northerly Lancaster Sound and that this provides opportunities for latitudinal and climatic comparisons and the development of generalized models.

PROGRAM PLANNING AND IMPLEMENTATION

Drinkwater noted that the workshop had generated many good ideas and sound justifications for the development of a comprehensive Hudson Strait research program. However, there are as yet no funds for implementing such a program. He suggested that a clearly defined and well co-ordinated program proposal that reflects the considerable degree of interdisciplinary interest that exists should increase the probability of obtaining funding. Percy agreed, but noted that in view of the large amount of information reviewed and discussed during the workshop there remains a great deal of synthesis and fine tuning to be done. He further stated that it is still too early to suggest either a single large program or several smaller interrelated programs.

Boulva assured participants that the ideas generated at the workshop and the recommendations of the Steering Committee will be carefully considered. However, he cautioned that DFO will likely want to concentrate primarily on species-specific TAC's of economically exploitable species and on the management of endangered species. However, he suggested that "the group" should continue to operate opportunistically in the meantime, particularly with respect to physical concerns (e.g. CTD and thermograph data collection etc.). The greatest chance of success in mounting a research program would probably result from the development of a comprehensive proposal for a process-oriented multi-disciplinary study focussing on the Hudson Strait region. However, such a program will require more critical appraisals and discussions, particularly in relation to DFO mandates, other wildlife concerns (e.g. birds, land mammals etc.) and the concerns of the local Inuit. A plausible approach might be to develop a multi-institutional proposal with DFO and universities playing a significant role and with some form of integrated NSERC-DFO funding.

Dunbar noted that the general public is becoming increasingly aware of escalating environmental problems and this widespread concern is now receiving more political attention. He continued that "we" as scientists need to be more involved in furthering the scientific education of the populace, but cautioned that the "Suzuki" approach may not be the most successful.

Legendre noted that Canada has a relatively poor record internationally in arctic research, particularly when compared with the Americans (Alaska region), the Norwegians and the Soviets. The evidence for this can be found in past and current strategic programs as well as in involvement in SCOR. The limited arctic research effort is really a reflection of a broader national science policy problem (NSERC, DFO etc.) in that the state of arctic research in Canada is much like that of a number of other scientific efforts that are lagging further and further behind the international community. The situation could be improved by encouraging the implementation of a "few" major initiatives in the Arctic in the near future. If this is not done we will lag even farther behind and will rapidly lose our remaining expertise and experience to the point where we should "forget" about arctic research. Dunbar suggested that the current "international attitude" pervading Ottawa may be favorable for the mounting of international arctic research programs. However, others noted they have unsuccessfully tried such an approach. The opinion was expressed that a majority of arctic researchers are externally funded foreigners and that most Canadian researchers cannot or choose not to work in the Arctic. However, Richard stated that operations at northern facilities such as the DIAND lab at Ikaluit do not appear to support such a contention. Sinclair suggested that more research than was apparent is being conducted in the Arctic and that the above criticisms may not be entirely justified. Finally, Dunbar noted that many university undergraduate and graduate students show great interest in the arctic regions and that this interest should be fostered and more opportunities made available to them to participate in arctic research.

The federal fiscal restraint policy is seen as one of the major impediments to a Hudson Strait research program at present, but this might be overcome by a concerted multidisciplinary planning effort and a clearly defined focus for the program. This Hudson Strait workshop represents an important first step in that direction.

SYNTHESIS OF WORKSHOP RECOMMENDATIONS

1. PHYSICAL OCEANOGRAPHY

1.1 CIRCULATION:

1.1.1 Improve our knowledge of the tidally-induced residual circulation in Hudson Strait.

1.1.2 Further modeling of the dynamics of the residual currents, especially the southwestward coastal current and the cross-channel flow in the eastern end of Hudson Strait.

1.1.3 Obtain reliable, quantitative estimates of the volume transport at both entrances of the Strait for use in budget studies, such as for heat, salt, nutrients, etc.

1.1.4 Assess the relative importance of the volume transports originating from Hudson Bay and Foxe Basin.

1.1.5 Study the circulation in the northwestern corner of Hudson Strait.

1.1.6 Obtain additional current records to determine the relative importance of low-frequency currents and their forcing mechanisms in various areas of Hudson Strait, especially near the two entrances and in Ungava Bay.

1.1.7 Collect additional moored current meter data, especially in the western half of Hudson Strait and Ungava Bay.

1.1.8 Carry out a comparative study of historical satellite imagery, to determine the large scale, recurrent oceanographic features of the Strait.

1.2 MIXING PROCESSES:

1.2.1 Determine the contribution to vertical mixing during the winter of sheer-induced turbulence resulting from the frictional drag of the ice cover on tidal currents. Studies in other arctic and subarctic areas indicate that when current velocities are high, vertical mixing can be intense.

1.2.2 Study the response to the tidal flow over the sill near the eastern end of the Strait. Theory would predict the generation of internal tidal waves.

1.3 T/S MEASUREMENTS;

1.3.1 Collect winter temperature and salinity data throughout Hudson Strait.

1.3.2 Carry out a detailed T,S analysis in order to quantify mixing rates and to better identify the origin of the water masses within Hudson Strait and Ungava Bay.

1.3.3 Carry out hydrographic measurements in winter, especially near the surface, to determine the seasonal variability in temperature and salinity.

1.3.4 Collect additional hydrographic data in Ungava Bay in all seasons.

1.4 FRESHWATER INFLUENCE:

1.4.1 Estimate the quantity of ice that is formed locally within the Strait and the quantity that is imported from outside.

1.4.2 Determine the fate of the sea-ice melt water and its role in the vertical stratification of the water column.

1.4.3 Estimate the proportion of the melt water that is transported out of the region on an annual basis.

1.4.4 Model the freshwater budget and flow from Hudson Bay to Hudson Strait to Labrador Sea.

1.5 GENERAL:

1.5.1 Carry out theoretical studies and numerical modeling of Hudson Strait physical oceanography.

1.5.2 Carry out a comprehensive study of the physical oceanography of Hudson Strait and its influence on the Labrador current.

1.5.3 Carry out comparative studies with oceanographic processes in Lancaster Sound and Gulf of St. Lawrence.

2. CHEMICAL OCEANOGRAPHY

2.1 GENERAL:

2.1.1 Investigate distributions of trace metals and other chemical constituents to help in tracking water masses and determining mixing rates of the water.

2.1.2 Measure oxygen isotope ratios (δO^{18}) to provide improved knowledge of the fate of ice-melt water and freshwater discharge within the Strait and Ungava Bay.

2.1.3 Determine if there is a significant export of nutrients and organic matter from the eastern entrance of Hudson Strait onto the Labrador Shelf (hypothesis of Sutcliffe *et al.* 1983).

3. PRIMARY PRODUCTION AND BACTERIAL SECONDARY PRODUCTION

3.1 PRODUCTION

3.1.1 Carry out measurements of primary and bacterial secondary production throughout Hudson Strait. There are no published measurements.

3.1.2 Carry out remote sensing of snow, ice and chlorophyll in order to determine the patterns of ice algal and phytoplanktonic primary production.

3.1.3 Determine the seasonal patterns of phytoplankton production and heterotrophic bacterial activity in order to ascertain the magnitude and duration of organic carbon production.

3.1.4 Study the hydrodynamic control of primary production, in particular the role of tidal mixing and currents.

3.1.5 Determine if there are areas of elevated primary production in Hudson Strait, particularly at the eastern and western entrances, and examine the oceanographic factors responsible (e.g. deep tidal mixing).

3.1.6 Study the differences in composition and ecology of the phytoplankton communities located at the eastern and western end of Hudson Strait in relation to the physical processes that drive them.

3.2 TROPHIC RELATIONSHIPS

3.2.1 Determine the fate of organic matter produced by primary production and examine the export pathways, including the microbial loop.

3.2.2 Determine if, and how, high primary production in certain areas in Hudson Strait is coupled to local food webs leading to shrimp, marine birds and mammals.

3.2.3 Determine phytoplankton and bacterial biomass downstream from areas of intense water mixing and measure the sedimentation of organic matter to the benthos.

4. ZOOPLANKTON ECOLOGY

4.1 DISTRIBUTION

4.1.1 Study the distributions and interactions of selected zooplankton indicator species in order to understand the dynamics of the waters in which they occur. This is especially important in eastern Hudson Strait where there is a need to identify the factors controlling the distribution and abundance of the potentially economically important species such as shrimp and Atlantic cod that are associated with Atlantic water.

4.1.2 Obtain additional baseline knowledge of the biodiversity, taxonomy and distribution of zooplankton in the region.

4.1.3 Determine if there are gradients in species composition of plankton along and across the Strait as a result of advection and mixing of different water masses in Hudson Strait.

4.2 ECOLOGY

4.2.1 Study zooplankton seasonal cycles.

4.2.2 Obtain information on the life history, ecology, habitat, reproduction, feeding habits, growth, diurnal and seasonal movements of the dominant zooplankton species.

4.2.3 Carry out basic studies on the biology and ecology of key species of zooplankton as well as studies of physical, chemical and biological interactions in order to understand community structure.

4.2.4 The differences in composition and ecology of the zooplankton communities located at the eastern and western end of Hudson Strait should be studied in terms of the physical processes that drive them.

4.3 TROPHIC RELATIONSHIPS

4.3.1 Determine the basic composition and interrelationships of the pelagic food web. Identify key species in the system as a first step toward understanding food web interactions and their influence on top predator productivity.

5. ICE BIOTA

5.1 PRODUCTION

5.1.1 Carry out studies on hydrodynamics and biological production under the ice cover in the Strait.

5.1.2 Determine if ice algal production in Hudson Strait is similar to production in northwestern Hudson Bay and follows the general model outlined in WELCH & BERGMANN (1989) that relates light and snow cover to ice algal growth.

5.1.3 Estimate the relative contribution of ice algal production to total primary production in various areas in Hudson Strait.

5.2 ECOLOGY

5.2.1 Study the effects of physical disturbance of ice biota by arctic sea transport.

5.2.2 Carry out basic studies on the biology and ecology of individual species of ice organisms as well as studies of the physical, chemical and biological interactions that are needed to understand community structure.

5.3 TROPHIC RELATIONSHIPS

5.3.1 Determine if the coupling between ice algal productivity and the marine food web is different in Hudson Strait than in Hudson Bay because of the strong tidal mixing in the former and if, therefore, most of the ice algal production in Hudson Strait goes to the benthos.

6. BENTHIC ECOLOGY

6.1 DISTRIBUTION

6.1.1 Obtain additional baseline knowledge about the biodiversity, taxonomy and distribution of benthic organisms in the region.

6.1.2 Study the differences between the benthic communities located at the eastern and western end of Hudson Strait in relation to the physical processes that drive them.

6.2 ECOLOGY

6.2.1 Obtain information about the life history, ecology, habitat, reproduction, feeding habits, growth, diurnal and seasonal movements of key benthic species.

6.2.2 Carry out studies of the physical, chemical and biological interactions that are needed to understand benthic community structure.

6.3 TROPHIC RELATIONS

6.3.1 Assess the magnitude and nature of the transfer of pelagic production to the benthos.

6.3.2 Measure the transfer of pelagic production to the benthos via filter feeders, and assess their importance in structuring benthic assemblages.

6.3.3 Study the coupling between benthic and pelagic systems.

6.3.4 Determine the relative importance of the pelagic versus the benthic food webs as one moves from east (subarctic) to west (arctic) in the Strait.

7. FISHERIES (INVERTEBRATES)

7.1 MUSSELS

7.1.1 Undertake basic studies on the biology and ecology of the blue mussel as well as studies of the physical, chemical and biological interactions that influence the populations.

7.1.2 Evaluate the yearly production and energy budget of an intertidal mussel-bed community, including the role of other dominant species (barnacles, gammarid amphipods, etc.).

7.1.3 Initiate a seasonal study of blue mussel gonad development, larval production and spat deposition, and determine the influence of physical (ice, temperature, circulation) and biological (phytoplankton bloom) conditions.

7.1.4 Evaluate the age structure of several populations of blue mussel and other molluscs, to determine if there are environmental constraints to recruitment, operating on a large geographical scale.

7.2 SCALLOPS (*Chlamys islandica*)

7.2.1 Continue exploratory fishing for scallop, and the collection of physical oceanographic data, in western Hudson Strait and northeastern Hudson Bay particularly in areas of intense water mixing.

7.2.2 Locate other areas of concentration of Icelandic Scallop and characterize their physical regime.

7.2.3 Undertake basic studies on the biology and ecology of scallops as well as studies of the physical, chemical and biological interactions that are needed to understand community structure.

7.2.4 Study the effects of major hydrographic features (fronts, gyres, etc.) on the biomass and production of the phytoplankton prey of scallops.

7.2.5 Study the effects of major hydrographic features (fronts, gyres, etc.) on larval scallop retention areas and the potential consequences for stock identification.

7.2.6 Obtain additional information about the biology of Icelandic scallop in Canadian arctic waters.

7.2.7 Study the linkage between phytoplankton abundance and adult growth, gonad maturation and larval release of Icelandic Scallop.

7.2.8 Study larval transport, population mixing and stock identification of Icelandic Scallop.

7.2.9 Carry out exploratory surveys for scallop in coastal areas using a lined dredge in order to collect small individuals and thus obtain information on the success of yearly recruitment.

7.2.10 Determine the effects of surface sediment enrichment (through production of fecal matter by Icelandic Scallop) on the benthic community.

7.2.11 Study the population dynamics of a virgin Icelandic scallop stock, and its response to various levels of exploitation.

7.2.12 Carry out a study of the energy budget and the use of bacteria and phytoplankton by scallops on specific beds.

7.3 SHRIMP (*Pandalus montagui*)

7.3.1 Obtain additional information about the biology, ecology and stock identity of *P. montagui*.

7.3.2 Study the life history and growth of *P. montagui*, because current models utilize values obtained for *P. borealis*.

7.3.3 Study the effects of major hydrographic features (fronts, gyres, etc.) on the biomass and production of the zooplankton prey of shrimp. Test hypothesis that pandalid shrimp are spatially associated with, and feed in, the zones of high production.

7.3.4 Study the influence of movements of water mass on the advection and retention of adults and larvae of shrimp. This will help determine if populations in the two areas (Resolution Island and Ungava Bay) are part of a single stock, or if they should be managed separately.

7.3.5 Study the predators of shrimp (turbot, cod, beluga) and their effects on population density. In the case of the beluga, there is concern that shrimp harvesting will deplete the whales' food supply.

7.3.6 The population of shrimp should be assessed and year-to-year variations of the commercial catches should be monitored, since there are indications that this area is subject to large-scale, long-term climatic or hydrographic fluctuations.

7.4 OTHER

7.4.1 Study the possibility of commercial exploitation of by-catch species such as sea cucumbers and sea urchins.

7.4.2 Study the effects of major hydrographic features (fronts, gyres, etc.) on the distribution and abundance of other potentially commercially-important species of invertebrates.

8. FISHERIES (FISH)

8.1 DISTRIBUTION

8.1.1 A comprehensive book on the taxonomy and distribution of arctic fishes is needed. To this end the book "Marine fishes of Arctic Canada" should be completed by the Canadian Museum of Nature.

8.1.2 The taxonomy of a number of arctic fish groups is in need of further study and revision, e.g. Zoarcidae and Cottidae.

8.1.3 Collect fish by midwater sampling, and especially by closing-net midwater sampling; the midwater species are little known in the area and poorly represented in museum collections.

8.1.4 Carry out subtidal sampling of fish by weasel trawls or scuba diving. The use of ichthycides might reveal the presence of previously unrecorded cryptic or nocturnal species.

8.1.5 Carry out a base-line multi-gear grid survey of the fishes of Hudson Strait, with representative voucher specimens preserved, otoliths, scales, sizes, weights and stomachs sampled, and relevant environmental parameters recorded. The data should be stored in a computerized geographic information system (GIS) and published as an atlas. Voucher material from this and other surveys should be deposited in the Canadian Museum of Nature.

8.1.6 Study the differences in composition of the fish communities located at the eastern and western end of Hudson Strait in relation to the physical processes that drive them.

8.1.7 Study the migration routes of anadromous fish, in relation to the general circulation patterns in coastal areas, using telemetry.

8.2 ECOLOGY

8.2.1 Carry out studies of the life history, behavior, and ecology of the lesser known fish species.

8.2.2 Carry out basic studies on the biology and ecology of commercially important species of fish as well as studies of the physical, chemical and biological interactions that are needed to understand community structure.

8.2.3 Carry out intensive studies on the population dynamics and ecology of arctic cod because of its overwhelming importance in the Strait's marine food chain.

8.2.4 Study the predator-prey relationships between demersal fish (cod, turbot) and shrimp in eastern Hudson Strait.

8.3 MANAGEMENT

8.3.1 Assess the levels of exploitation of selected arctic marine fish species.

8.3.2 Determine the factors limiting the abundance and distribution of fish of commercial importance in the Strait.

8.3.3 Determine the possible importance of the Strait as a nursery area for certain species of demersal fish (turbot).

9. SEABIRDS

9.1 DISTRIBUTION

9.1.1 Determine the nature and magnitude of the autumn (September/October) influx of birds into the Strait. Virtually nothing is known about this at present.

9.1.2 Study general seabird distributions during the non-breeding season.

9.2 ECOLOGY

9.2.1 Study the ecology of common eiders along the north shore of the Strait and in Ungava Bay.

9.2.2 Examine the possibility of using seabirds as early indicators of marine environmental changes.

9.3 TROPHIC RELATIONSHIPS

9.3.1 Examine the possibility of competition between thick-billed murres and ringed seals in view of the similarity in life-history parameters and food requirements.

9.1.2 Monitor puffin numbers as an index of capelin abundance in certain areas of the Strait.

9.1.3 Determine the effect of eiders on the benthic invertebrate community in the shallow waters (mainly less than 10m) where they feed.

9.1.4 Seek a satisfactory explanation for the low diversity, but high abundance, of seabirds in Hudson Strait compared to other areas of the arctic and subarctic.

9.1.5 Obtain information about the behaviour of the prey of murres (e.g. spatial, diurnal and seasonal patterns of vertical distribution of fish and zooplankton prey).

9.1.6 Carry out collaborative studies involving marine ornithologists and other marine biologists on the feeding energetics of seabirds in Hudson Strait.

9.1.7 Carry out studies on the marine prey of seabirds in vicinity of Akpatok Island.

9.1.8 Test hypothesis that thick-billed Murres are spatially associated with, and feed in, the zones of high marine production.

10. MARINE **MAMMALS**

10.1 RINGED SEAL

10.1.1 Delimit and evaluate the summer and winter habitats of ringed seals in Hudson Strait and Ungava Bay.

10.1.2 Carry out studies on the ecology and production of ringed seal populations in various parts of Hudson Strait and Ungava Bay. Some information is available about populations in the northwestern region of the Strait, but not for other areas.

10.2 BELUGA

10.2.1 Carry out stock assessment and stock identification work on the Ungava beluga population which appears to be threatened.

10.2.2 Monitor the stock of belugas in eastern Hudson Bay and James Bay where the harvest is close to the calculated sustainable yield.

10.2.3 Sample the subsistence catch of belugas in Ungava Bay and Hudson Strait for tissues for use in DNA analyses aimed at stock identification.

10.2.4 Determine stock discreteness of beluga populations in the Hudson Strait region. Identify the different stocks using the Strait and determine if they have distinct distributions.

10.2.5 Study the activities of the Hudson Bay beluga population during the 6 months or more (winter) that they spend in Hudson Strait. This would involve systematic winter aerial surveys accompanied by detailed sampling of animals on the ice.

10.2.6 Obtain estimates of natural and harvesting mortality for exploited beluga populations.

10.2.7 Obtain information on the energetics of belugas to determine interactions with their food base and the possible effects of commercial harvesting of food species.

10.2.8 Determine the critical habitats for belugas in Hudson Strait.

10.2.9 Test hypothesis that over-wintering belugas are spatially associated with, and feed in, the zones of high production.

10.3 WALRUS

10.3.1 Determine their abundance and distribution in Hudson Strait.

10.3.2 Study the stock discreteness of various walrus populations in the Hudson Strait region. Stock identities could be studied through DNA analyses as well as through satellite tracking.

10.3.3 Determine the winter distribution of walruses in the Hudson Strait region.

10.3.4 Study the food and feeding habits of Walruses in Hudson Strait region. Carry out a comprehensive benthic survey in the vicinity of one or more haulout sites, along with observational studies of the walruses at the site and studies of the oceanographic features which shape and sustain the benthic community there.

10.3.5 Carry out studies to determine why the distribution range of walrus is declining.

10.4 NARWHAL

10.4.1 Obtain estimates on natural and harvesting mortality for narwhal populations in Hudson Strait.

10.4.2 Determine the stock discreteness of narwhal population in Hudson Strait.

10.4.3 Obtain information on the energetics of narwhals to determine interactions with their food base and the possible effects of commercial harvesting of food species.

10.4.4 Determine the critical habitats for narwhals in Hudson Strait.

10.5 BEARDED SEAL

10.5.1 Determine the abundance and distribution of bearded seals in Hudson Strait.

10.5.2 Study the food and feeding habits of bearded seals in Hudson Strait, particularly their possible utilization of the high benthic biomass in certain areas.

10.6 HARP SEAL

10.6.1 Determine abundance and distribution of harp seals in Hudson Strait.

10.6.2 Monitor apparent changes in the use of Hudson Strait during the summer by harp seals from the Canadian east coast. The population may be increasing rapidly and expanding its range as a result of the curtailment of the east coast seal hunt.

10.6.3 Study the ecology of harp seals. They are increasing in abundance and feed intensively in Hudson Strait during the summer and autumn. Evaluation of their potential impact on southern fisheries during the winter months requires information about their utilization of, and dependence upon, arctic food resources.

10.6.4 Assess the possibility of harvesting harp seals in Hudson Strait.

10.7 GENERAL

10.7.1 Carry out basic studies on the biology and ecology of individual species of marine mammals as well as studies of the physical, chemical and biological interactions that are needed to understand community structure.

10.7.2 Carry out extensive marine mammal fieldwork in the Strait during the winter. Surveys in winter and spring might be made from ice reconnaissance aircraft.

10.7.3 Carry out studies on the predation of polar bears on marine mammals in Hudson Strait.

10.7.4 Determine the critical factors which are likely to affect distribution and abundance of marine mammals in the region (e.g. pattern in natural mortality, prey abundance, disruption of migratory pathways).

10.7.5 Monitor some target populations of marine mammals over a long period of time.

11. ENVIRONMENTAL IMPACTS

11.1 CLIMATE CHANGE

11.1.1 Initiate a monitoring program to study the effects of global atmospheric warming on sea temperatures in Hudson Strait and assess the effects on marine biota.

11.1.2 Initiate a monitoring program to study the increasing penetration of the ocean surface by ultra-violet rays and assess the effects on marine biota.

11.1.3 Study the possibility of using certain marine species as indicators of climate change. The Hudson Strait area is at the northern distribution limit of several species of commercial interest. Species whose distribution could be monitored include: Atlantic salmon, capelin, Atlantic cod off Killinek, as well as the growth pattern of mussels. Two types of indicators could be measured:

1) the monitoring of year-to-year variations in catch rates in selected areas
2) evaluating the year-class strength and monitoring variable recruitment.

11.1.4 Study the distribution and abundance of selected planktonic indicator species such as various copepod species or species of hyperiid amphipods, which show distinct latitudinal, temperature, and water mass preferences in their geographic distribution and origin. Identifying their distributions could be useful in monitoring climatic change and related large scale variations in the ocean environment.

11.1.5 Initiate a long-term monitoring program for various other physical and biological features of the marine environment. Involve local people as monitors responsible for collecting basic physical and biological information. Obtain a long-term TIME SERIES of observations of such things as:

1) temperature and salinity changes in the sea.
2) air temperature changes (already being supplied by AES).
3) river discharge variations.
4) changes in selected populations of organisms.

11.1.6 Establish two oceanographic sampling stations, one at either end of the Strait for monitoring a variety of relevant variables, such as temperature, salinity, chlorophyll, plankton biomass, etc. This will allow for both hindcasting: using old data series to address questions, as well as forecasting: making predictions about oceanographic change.

11.2 CONTAMINANT TRANSPORT

11.2.1 Monitor relevent contaminants such as PCB'S, hydrocarbons, trace metals and radioactivity in the Hudson Strait marine environment and identify their sources.

11.2.2 Collect tissue samples from fishes and other marine organisms in the food chain for analysis of contaminants. Standard stations and methods should be established for periodic monitoring of contaminants.

11.2.3 Set up a tissue bank of samples from northern marine species a soon as possible to be used for future assessments of presently unknown contaminants, baseline levels of contaminants, long-term trends in contaminants etc.

11.2.4 Obtain a long **TIME SERIES** of observations of such things as:
1) concentrations of selected pollutants in the environment.
2) changes in pollutant concentrations within organisms
3) changes in selected populations of organisms.

11.2.5 Study the long-distance transport of selected pollutants (via the atmosphere, rivers and ocean currents) into the Hudson Strait marine environment and assess their importance and the biological implications.

11.3 HYDROELECTRIC DEVELOPMENTS

11.3.1 Improve our understanding of physical oceanographic processes within Hudson Strait in order to evaluate the effects of seasonal and year-to-year variations in run-off in James, Hudson and Ungava bays.

11.3.2 Evaluate the effects of seasonal and year-to-year variations in run-off in James, Hudson and Ungava bays on primary and secondary planktonic production in Hudson Strait.

11.3.3 Carry out a variety of baseline biological studies in order to monitor and assess the cumulative effects on the Hudson Strait marine environment and ecosystem of future hydroelectric development of the rivers of Hudson Bay and Ungava Bay.

11.3.4 Determine the impacts of the existing and plannned James and Hudson Bay hydroelectric schemes on the fish populations of Hudson Strait. Determine the impact of changed annual thermal and salinity regimes on inshore and anadromous species of fish.

11.3.5 Further evaluate the hypothesis of Sutcliffe *et al.* (1983) concerning the influence of runoff on mixing in Hudson Strait and the injection of nutrients into the Labrador Sea by incorporating data obtained since the development of the La Grande complex. Determine if this phenomenon exists and if so, how important it is ecologically.

11.3.6 Carry out studies to evaluate the role of terrestrial organic input by major rivers, particularly in Ungava Bay, to the marine environment and the influence on production in coastal waters.

12. GENERAL RECOMMENDATIONS

12.1 PROGRAMS

12.1.1 To conserve and manage our arctic ecosystems in a responsible manner we need to invest heavily in the acquisition of baseline information.

12.1.2 Research program in all areas of oceanography and marine biology must extend through the winter months if we are to obtain an adequate understanding of the Hudson Strait ecosystem.

12.2 PERSONNEL

12.2.1 Appropriate funding agencies should provide scholarships for young Inuit to pursue careers in fisheries, marine biology, and systematics of arctic fauna and flora.

12.2.2 The role of native people in managing biodiversity, ecosystems and marine resources needs to be affirmed.

12.3 FACILITIES

12.3.1 Establish a permanent marine biological station in the Hudson Strait area to support oceanographic and marine biological research programs in general and to facilitate long term monitoring of the effects of climate change, contaminant input and industrial development on the marine environment.

12.3.2 The role of the DFO Arctic Biological Station at Ste-Anne-de-Bellevue, Quebec, as a major centre for marine biological research in northern Quebec should be affirmed and additional resources should be provided to carry out its work.

12.3.3 Consider the possibility of using a suitably outfitted barge for carrying out monitoring and other scientific programs. Permits greater portability than a land base and has greater fixed position capability than a vessel.

12.3.4 Provide adequate large vessel support for large scale oceanographic and biological studies during initial phase of program.

12.3.5 Provide suitable small dedicated research vessel based in the north for continuing studies of specific oceanographic and ecological processes and selected populations of marine organisms in various parts of Hudson Strait.

THE HUDSON STRAIT

MARINE ECOSYSTEM:

AN OVERVIEW

GEOGRAPHY AND BATHYMETRY

J.A. Percy

Department of Fisheries and Oceans
Arctic Biological Station
555 boul. St-Pierre
Ste-Anne-de-Bellevue, Québec, H9X 3R4

This brief description of the general geography and bathymetry of Hudson Strait is largely synthesized from information presented in DUNBAR (1952; 1958), CAMPBELL (1958), CANADIAN HYDROGRAPHIC SERVICE (1983); GASTON *et al.* (1985) and DRINKWATER (1986), as well as from recent hydrographic charts of the region.

GEOGRAPHY

Hudson Strait is part of an elongated submerged valley lying north of 60^{o} that separates the Ungava Peninsula of northern Quebec from Baffin Island in the Northwest Territories (Fig. 1). From its Atlantic entrance near Resolution Island to the head of Frozen Strait at the base of Melville Peninsula this trough is

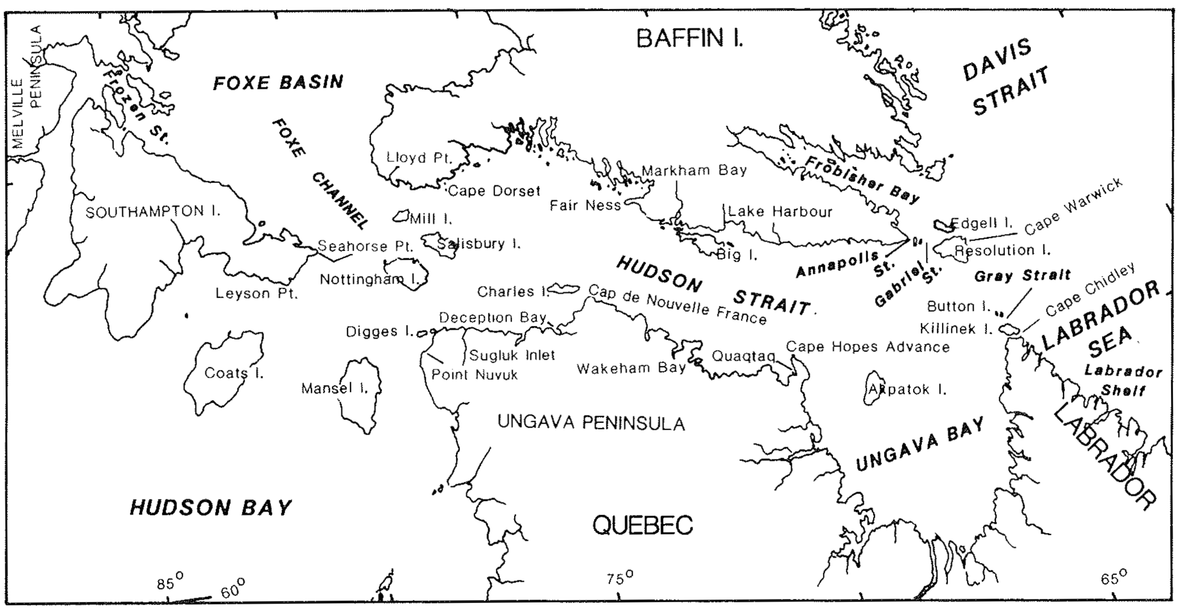

Figure 1. Map of Hudson Strait and vicinity, indicating locations referred to in the text.

about 1200 km in length. It trends in a northwesterly direction from its eastern entrance and links Foxe Basin and Hudson Bay in the West to the Labrador Sea and Davis Strait to the east. It thus provides ready access during the summer from the North Atlantic to Hudson Bay and James Bay in the interior of the north American continent.

Hudson Strait proper, however, encompasses only the eastern two-thirds of this submerged valley. According to the CANADIAN HYDROGRAPHIC SERVICE (1983) the westernmost limit of the Strait is defined as follows: the boundary between Hudson Strait and Foxe Channel is the line joining Lloyd Point (64°26'N, 78°02'W), on Baffin Island to Seahorse Point on the eastern extremity of Southampton Island; and the boundary between Hudson Strait and Hudson Bay is the line joining Point Nuvuk on the northwestern extremity of the Ungava Peninsula to Leyson Point on the southeastern extremity of Southampton Island. Thus, the actual length of the Strait between its eastern and western entrances is about 900 km. It varies in width from a minimum of about 70 km at the eastern entrance to a maximum of approximately 240 km at the longitude of Sugluk Inlet. The average width is about 125 km.

Both the northern and southern coasts of the Strait are rocky, treeless and barren with frequent high cliffs rising precipitously from the sea. The northern coastline in particular is very irregular with many inlets, bays and islands, especially towards the western end of the Strait between Fair Ness and Cape Dorset. Coastal elevations range from 120 to 180 m with a gradual rise to over 300 m 20 km inland. The southern coastline has fewer inlets and small islands, but several deep, narrow fjords, such as Deception, Sugluk and Wakeham bays, that penetrate up to 30 km into the coast. West of Ungava Bay this coastline is generally higher and more precipitous than the Baffin Island coast, particularly towards the western entrance, where a precambrian mountain chain forms the backbone of the northern Ungava Peninsula. In some places the mountains rise steeply to heights of over 300 m within 10 km of the coast.

The eastern entrance of the Strait consists of five principal channels. The largest of these, between Resolution Island and the Button Islands, is about 70 km wide and opens into the Labrador Sea. Two smaller channels, Gabriel and Annapolis straits, lying between Resolution and Baffin islands, link Hudson Strait to the mouth of Frobisher Bay and Davis Strait. To the south, Gray Strait, between the Button Islands and Cape Chidley on Killinek Island, and the 25 km long McLelan Strait between Killinek Island and the Labrador mainland, open into the Labrador Sea and the northern Labrador Shelf.

There are three principal channels at the western entrance of the Strait. The largest of these, the main passage into Hudson Bay to the southwest, lies between Southampton Island and the Digges Islands and is about 160 km wide. To the northwest, Foxe channel between Baffin Island and Southampton Island is almost 120 km wide and connects Hudson Strait to Foxe Basin. The smallest entrance, Digges Sound, lying between east Digges Island and the Quebec mainland, is 5-7 km in width and also connects the Strait with northwestern Hudson Bay.

Ungava Bay is a large, U-shaped body of water lying just within the eastern entrance of Hudson Strait and extending directly southward. It is about 200 km across at the mouth, between Cape Chidley in the East and Cape Hopes Advance to the west, and about 250 km from north to south. The high rugged coasts in the northern part of the Bay , characteristic of the Hudson Strait area, give way in the south to a low, undulating terrain that rises gradually inland to elevations up to 150 m.

The total surface area of Hudson Strait and Ungava Bay together is about 188 x 10^3 km^2 (DRINKWATER, 1986). This represents about one-third the area of Hudson Bay and more than three quarters of the area of the Gulf of St. Lawrence. The principal rivers in the Hudson Strait region all flow into the southern half of Ungava Bay. In order of decreasing discharge they are the Koksoak, George, Leaf, Whale and Payne rivers. In addition, many other small rivers and streams drain into Ungava Bay and into bays and inlets along both coasts of Hudson Strait.

There are several large islands in the Strait and many thousands of smaller ones. The two largest are Resolution and Nottingham islands. Digges, Nottingham, Salisbury and Mill islands lie across the western entrance, while Resolution, Button and Killinek islands straddle the eastern entrance Two large islands, Big and Charles, are located on either side of the Strait towards its midpoint. Akpatok Island, located towards the western side of the mouth of Ungava Bay, is a bare, flat-topped limestone massif of Palaeozoic origin, geologically different from the adjacent mainland, and separated from it by a 200 m deep channel.

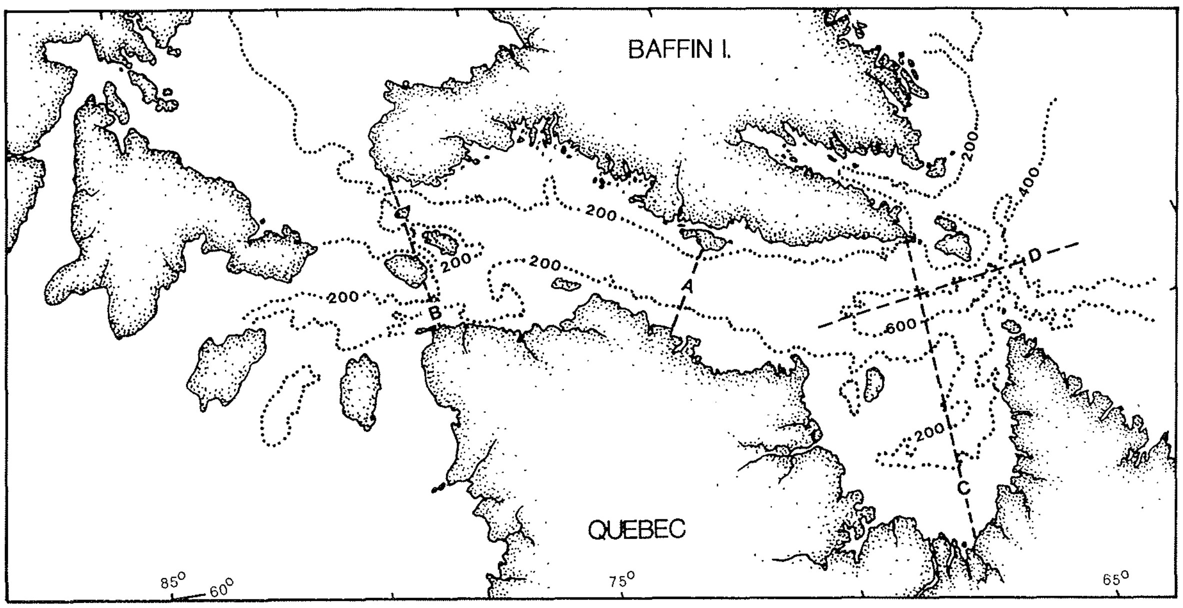

Figure 2. The bathymetry of Hudson Strait. 200, 400 and 600 m depth contours indicated. Dashed lines indicate transects for bottom profiles presented in Figures 3-6.

BATHYMETRY

The general bathymetry of the Strait is reasonably well known (Fig. 2), although detailed information is lacking for many areas and only a small part of Hudson Bay and Strait have been surveyed to modern standards (CANADIAN HYDROGRAPHIC SERVICE, 1983).

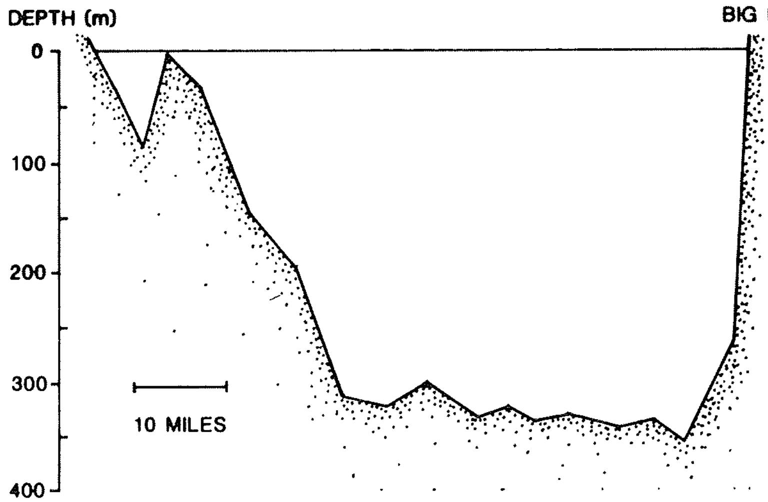

Figure 3. Bottom profile along transect A between Big Island and the Québec coast near Wakeham Bay.

The Strait has an uneven bottom topography reflecting the ruggedness of the surrounding mountainous coastal terrain. Its principal feature is a U-shaped trough, with steep sides and depths exceeding 300 m (Fig. 3), extending from the eastern entrance to Foxe Channel. In the vicinity of the western entrance the main channel branches to either side of the Nottingham and Salisbury island group (Fig. 4). One channel continues northwestward into southern Foxe Basin and Frozen Strait. The other smaller branch slices westward into northern Hudson Bay. The 200 m depth contour is generally found within about 15 km of the coast in most areas (Fig. 2). The most notable exceptions are the shallow southern and western portions of Ungava Bay and the relatively broad shelf bordering the arc of coast between Fair Ness and Cape Dorset.

Ungava Bay is effectively a submerged plateau and is much shallower than Hudson Strait (Fig. 5). It is less than 150 m in depth over much of its area, and less than 100 m deep in the southern and western regions. At its northern edge this plateau drops off sharply into the main channel of the Strait. In fact, the 400 m contour defines the northernmost boundary of Ungava Bay. A 200-400 m deep channel extends from the deep depression within the eastern entrance to the Strait into the eastern side of the Bay. This channel extends southwest from Cape Chidley to about the midpoint of the Bay before curving around northward to terminate just west of Akpatok Island. The bottom topography of Ungava Bay is rough, very irregular and generally rocky with heavy glacial mud and sand. It is ridged and heavily bouldered, "giving the impression of a terrain recently glaciated, probably filled with numerous eskers and lateral moraines, and with too short a lapse of time since the retreat of the ice to allow sedimentation to exert any great smoothing effect" (DUNBAR 1958). It is also possible that the strong tidal currents have impeded the deposition of sediments in the area.

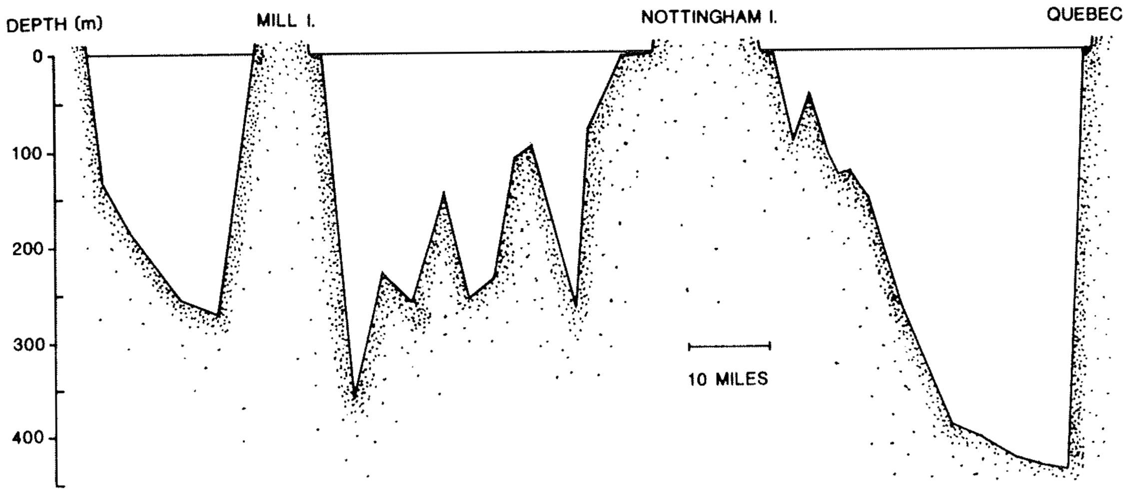

Figure 4. Bottom profile along transect B between the Baffin coast near Cape Dorset and the Québec coast near the Digges Islands.

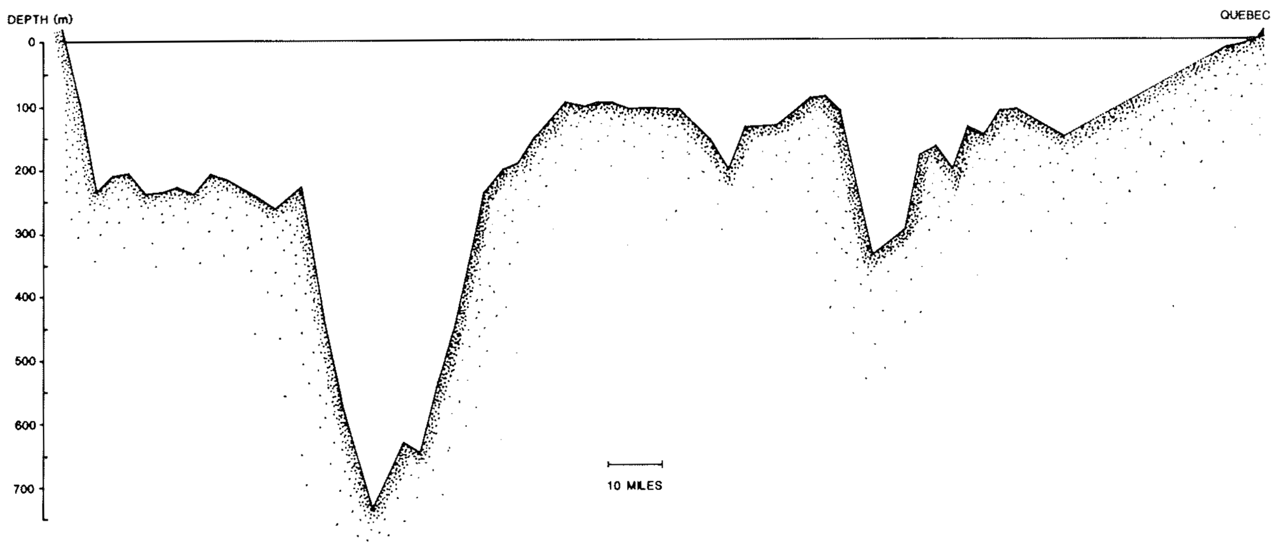

Figure 5. Bottom profile along transect C between the Baffin coast adjacent to Annapolis Strait and the Québec coast at the foot of Ungava Bay.

Three particularly deep water areas occur in the region. The largest and deepest of these lies just within the eastern entrance of the Strait, to the north of Ungava Bay. Here depths exceed 900 m. A 400 m deep sill between Resolution Island and the Button Islands separates this depression from the Labrador Sea to the east (Fig. 6). Gabriel, Annapolis and Gray straits, the other eastern entrances to Hudson Strait are at most 300 m deep. Another deep basin, some 500 m in depth, is located in the southwestern channel branching into Hudson

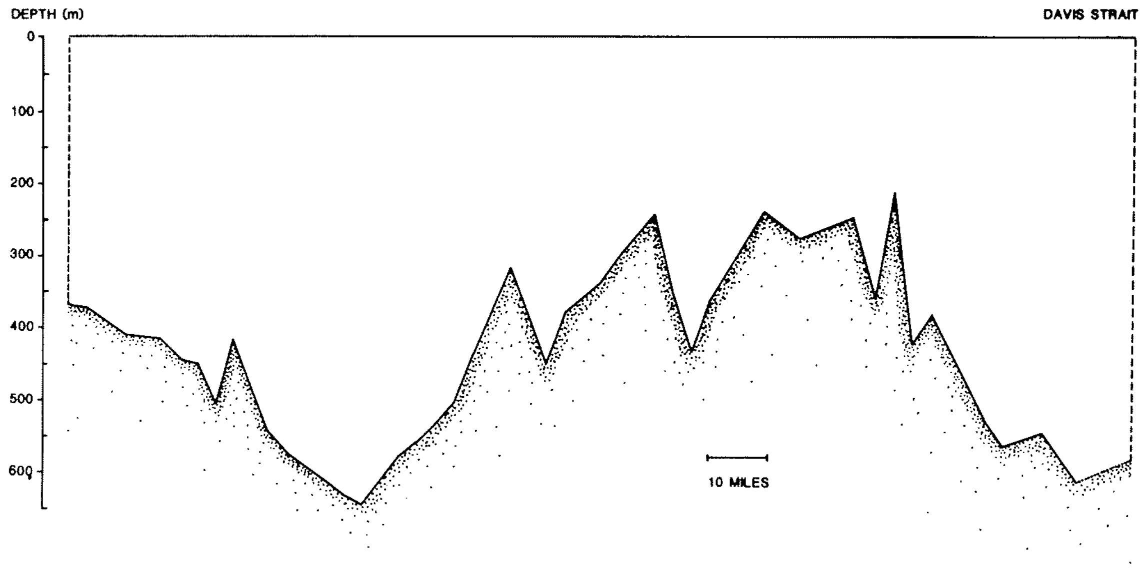

Figure 6. Bottom profile along transect D through the eastern entrance to Hudson Strait.

Bay immediately to the north of the Digges Islands. The 200 m depth contour of this basin lies less than 1 km offshore from eastern Digges Island. This depression is largely isolated from the main channel of the Strait by a shallow ridge that runs between Charles Island and Salisbury Island. However, a narrow deep channel cuts across this ridge near its midpoint, providing some connection between the deeper water of the Digges Islands basin with that of the main channel of Hudson Strait.

REFERENCES

CAMPBELL, N.J. 1958. The oceanography of Hudson Strait. **Fish. Res. Board Can., MS. Rep. Ser. (Oceanogr. Limnol.)** No. 12, 60 pp.

CANADIAN HYDROGRAPHIC SERVICE. 1983. **Sailing directions, Labrador and Hudson Bay**. 5th edition. Department of Fisheries and Oceans, Ottawa. 450 pp.

DRINKWATER, K.F. 1986. Physical oceanography of Hudson Strait and Ungava Bay. Pp. 237-264 *In*: Martini, I.P. (ed). **Canadian Inland Seas**. Elsevier Oceanography Series 44, N.Y.

DUNBAR, M.J. 1952. Contribution to the study of the fishes of Ungava Bay. **J. Fish. Res. Board Can.** 9(2):83-128.

DUNBAR, M.J. 1958. Physical oceanographic results of the "Calanus" expeditions in Ungava Bay, Frobisher Bay, Cumberland Sound, Hudson Strait and northern Hudson Bay, 1949-1955. **J. Fish. Res. Board Can.** 15(2):155-201.

GASTON, A.J., D.K. CAIRNS, R.D. ELLIOT & D.G. NOBLE. 1985. A natural history of Digges Sound. **Can. Wildlife Serv. Rep. Ser.** 46. 63 pp.

ICE CONDITIONS AND CLIMATE

J.A. Percy

Department of Fisheries and Oceans
Arctic Biological Station
555 boul. St-Pierre
Ste-Anne-de-Bellevue, Québec, H9X 3R4

ICE CONDITIONS IN HUDSON STRAIT

Hudson Strait is ice covered for almost three quarters of the year, usually being free of ice only from early August until late October. There is considerable variability from year to year and the timing of autumn freeze-up and spring break-up can deviate from the average by as much as a month (DRINKWATER 1986). The bulk of the ice in the Strait is first year ice of local origin (CANADIAN HYDROGRAPHIC SERVICE 1983), but a large and highly variable volume of ice is also transported into the Strait by wind and currents through both the eastern and western entrances.

Local ice formation usually begins in late October or early November in the nearshore waters of the Strait and Ungava Bay. Offshore, the ice normally begins to appear in quantity during the second half of November. Typically, the ice accumulates at the western end of the Strait and freeze-up progresses eastward until eventually the whole Strait is covered by unconsolidated pack ice by late November or early December (CANADIAN HYDROGRAPHIC SERVICE 1983).

The time of freeze-up is largely dependent on the broad-scale patterns of atmospheric circulation in the region (CRANE 1978). Late ice years are usually associated with a high percentage of easterly winds induced by large low pressure systems centered over northern Quebec, southern Davis Strait or southwestern Greenland. Such easterly winds ameliorate the ice conditions in Hudson Strait by retarding the southward drift of ice from Foxe Basin and by feeding warmer air into the region, thus slowing the onset of freeze-up. In contrast, during early ice years the winds tend to blow from the north or west about a prevailing low pressure system situated over central Baffin Island. The northerly winds enhance the southward drift of ice and increase the amount entering the Strait from Foxe Basin in the west and from the Davis Strait in the east. They also feed colder air into the region and thus hasten the onset of freeze-up. Although ice conditions in Hudson Strait are frequently heavy, the sea never freezes over completely (FORWARD 1956; MONTGOMERY 1949). Most of the ice consists of unconsolidated first-year floes that are constantly moved about by wind and currents. The only stable ice cover consists of relatively narrow strips of landfast ice in sheltered coastal regions and around some of the larger islands of the western Strait. This fast ice grows to 60-75 cm in thickness by early January and attains a maximum thickness of 110-160 cm by mid-May (CANADIAN HYDROGRAPHIC SERVICE 1983). The fast ice surrounding some of the islands can be as much as 9 km wide, while along the northwest coast of Quebec the fast ice zone is usually less than 4 km in width (MONTGOMERY 1949). The most extensive areas of landfast ice are to be found in the western Strait along the convoluted and island studded coast of Baffin Island between Cape Dorset and Fair Ness, where the fast ice zone may be up to 30 km in width (MCLAREN 1958), and in northeastern Hudson Bay in the vicinity of the Digges Islands and their associated archipelago (GASTON *et al.* 1985). Along the eastern shore of Ungava Bay the shelf of fast ice may be up to 15 km wide (MONTGOMERY 1949). In most other coastal areas steep, regular shorelines and powerful tidal action severely limit the development of fast ice.

Offshore in the Strait, the strong tidal currents and frequent winter gales keep the ice in almost constant motion, preventing the formation of a solid ice cover. The ice movement causes extensive lead systems to open and close rapidly and sporadically. In areas where there is heavy lateral pressure on the ice, considerable ridging, rafting and hummocking of the floes may greatly increase its thickness.

These dynamic processes ensure that the amount and distribution of ice in Hudson Strait vary greatly in different areas and at different times. In general, the severest ice conditions in the Strait occur in the western entrance where the flow of ice from Foxe Basin and Hudson Bay sometimes chokes the narrow channels between the islands. Congested ice conditions can also occur along the south side of the Strait when northerly winds prevail. In much of the Strait, ice conditions are generally quite variable; light ice conditions when winds are offshore and heavier conditions when winds are onshore. In some areas ice conditions are often characteristically light. One such area lies off the Baffin Island coast between Resolution Island and Big Island. Here there are frequent large open leads or very light ice conditions, especially after freeze-up and before break-up and usually sporadically throughout the winter. This situation, which has been characterized as a recurring shorelead system (STIRLING 1981), is caused largely by prevailing winds from the northwest (CATCHPOLE & FAURER 1983). STIRLING (1981) reports the presence of a similar recurring shorelead system further to the west between Cape Dorset and Fair Ness. CAMPBELL (1958) suggests that an intrusion of water into the Strait from Baffin Bay, and the turbulence of the water west of Fair Ness, may also contribute to these unusual ice conditions. Ice conditions within the eastern entrance of the Strait can vary greatly as strong tidal currents keep the ice in almost constant motion and strong winds cause extensive lead systems to open and close periodically. MONTGOMERY (1949) reported that narrow, deep channels, such as Gray Strait in the east and Digges Sound in the west, are usually clear of ice through much of the winter because of the very strong currents sweeping through them. During spring break-up, these same currents choked the channels with heavy ice for some time after the surrounding area cleared. However, winter ice charts from 1981 to 1987 show these same two channels covered with consolidated fast ice for much of the winter (P.W. Cote, pers. comm.).

The ice conditions in the Strait are particularly influenced by the extent, distribution and movement of the Baffin Bay/Davis Strait pack ice off the eastern entrance. This ice not only intrudes into the Strait but can, when particularly heavy, impede the normal eastward flow of unconsolidated ice out of the Strait on the southern side. Freeze-up in Baffin Bay and Davis Strait is a lengthy process. It begins in the northwest section of Baffin Bay during the second half of September and spreads southward along the west side to the approaches to Frobisher Bay by the second week of November. Some of this ice and the entrained icebergs moving southward with the Baffin Island current veer westward into the

Strait. Easterly winds in particular can drive a large quantity of pack ice into the Strait. The pack consists mostly of first-year ice but often includes many older floes. The southward flow of heavy ice and westward intrusion into the Strait continue until late July. This Baffin Bay floe ice mostly remains east of 70^{o} W but some does penetrate as far into the Strait as Big Island.

FREEZE-UP

A great deal of floe ice from Hudson Bay and Foxe Basin also penetrates into the Strait through the western entrances (DANIELSON 1971). Ice from Foxe Basin can be flushed out into Hudson Strait at almost any time of the year and even during the summer large floes may be encountered in the western Strait. Normally, in late October or early November but occasionally in early September, heavier intrusions of ice from Foxe Basin drift into the western end of Strait. Freeze-up tends to occur earlier in Foxe Basin and Foxe Channel than in the Strait itself. The ice from Foxe Basin is almost all first-year ice, although when summers are particularly cold some ice may persist in Foxe Basin and then enter the Strait the following year. Foxe Basin ice is characteristically very rough and discolored. Its roughness is due to the ridging and rafting caused by severe stresses from tidal and wind action. Its muddy color is attributed to the fact that the shallowness of Foxe Basin combines with a large tidal range and frequent high winds to keep large quantities of sediment in suspension, and this eventually freezes into the ice.

BREAK-UP

Break-up in Hudson Strait typically begins in late May or early June. The ice generally clears first in the vicinity of the recurring shore leads along the south Baffin Island coast and by late May there are often extensive areas of open water in this area. Also, the relatively warm outflow from Hudson Bay often clears ice from between the Digges Islands and Charles Island well before other regions of Strait and sometimes delays freeze-up in the autumn (CAMPBELL 1958).

Throughout May and June the leads grow more extensive as the temperature rises and less re-freezing occurs. Break-up and ice melting gradually spread throughout the whole area. Melting occurs slowly until July, after which it becomes more rapid. The landfast ice eventually breaks away from the shore and mingles with the drifting pack. By late July extensive ice floes generally persist only in central Ungava Bay and along the southern side of the Strait. In some years the Strait is essentially ice free by mid-July. However, complete clearing of ice from the Strait more normally occurs during the first or second week in August. From then until freeze-up the only ice found usually consists of icebergs from Davis Strait or floes periodically intruding from Foxe Basin.

ICEBERGS

The icebergs that drift into eastern Hudson Strait are mostly calved from the glaciers of the Greenland icecap. These drift counter clockwise around Baffin Bay for up to two years and then southward with the Baffin Island Current. Some, driven by currents and wind, enter northeastern Hudson Strait through Gabriel Strait or around the southern flank of Resolution Island (MARKHAM 1988). The majority drift southward to the Quebec coast and begin moving eastward well before they reach Big Island. A few, however, have been sighted as far west as Charles Island (LARDNER 1968), Nottingham Island (MCLEAN 1929) and even in Foxe Channel in 1958 (E.H. GRAINGER, pers. comm.). Many of them drift into Ungava Bay where they either ground and melt or are carried by the Hudson Strait outflow eastward past Cape Chidley to continue their journey south in the Labrador Current. ANDERSON (1971) calculated that about 270 icebergs circulate through the Strait in an average year, primarily in summer. However, EBBESMEYER *et al.* (1980) have pointed out that this estimate is based on data for years when iceberg concentrations in Davis Strait were far lower than the longer term average. They suggest a correction factor yielding a long-term average of about 640 icebergs per year entering the Strait.

THE CLIMATE OF HUDSON STRAIT

TEMPERATURE

The climate of Hudson Strait is decidedly polar in nature, with the mean monthly air temperature rising above 0°C for only 4 months (June-September) of the year (Fig. 7). During the warmest month (July), the 7°C isotherm generally coincides with the southern coast of Strait and the mouth of Ungava Bay. The area is considerably colder than most other regions at comparable northern latitudes (CANADIAN HYDROGRAPHIC SERVICE 1983). Air masses originating over the Arctic Islands to the north tend to dominate the climate of the Strait (BRYSON & HARE 1974). In winter, the air tends to be cold and dry and of a more continental character. However, in summer this cold air mass usually shifts northwards and a warmer, moister more maritime system strongly influences the area.

In addition, throughout the year, there is evidence of a distinct climatic gradient along the length of the Strait, with the western part tending to be more arctic continental and the eastern part more polar maritime (CAMPBELL 1958). This marine influence is felt both summer and winter and is attributable to the presence of open water in the Labrador Sea and Davis Strait. As a result, the eastern end of Hudson Strait is subjected to the greatest marine influence of any area in the Arctic Archipelago (MAXWELL 1981).

The seasonal range of the monthly mean air temperatures (Fig. 7) tends to be more extreme towards the west ($\approx$ 30°C) than in the east ($\approx$ 21°C). The monthly mean air temperature ranges from a high of about 3° to 6°C in July-August, to a low of about -18° to -24°C in January-February (CANADIAN HYDROGRAPHIC SERVICE 1983). In summer the warmest temperatures are recorded at Nottingham Island near the western end and the lowest at Resolution Island near the eastern entrance. The latter are largely attributable to the presence of relatively cold water, in part due to intense vertical mixing. In fact, the mean temperature in July at Resolution Island is almost the lowest in the whole of the Arctic Islands in spite of the fact that it is the most southerly location (MAXWELL 1981). Conversely, in winter the lowest monthly mean temperatures are recorded at the western end of the Strait and the highest at the eastern end, due to the moderating influence of the relatively open water of the Labrador Sea and South Davis Strait.

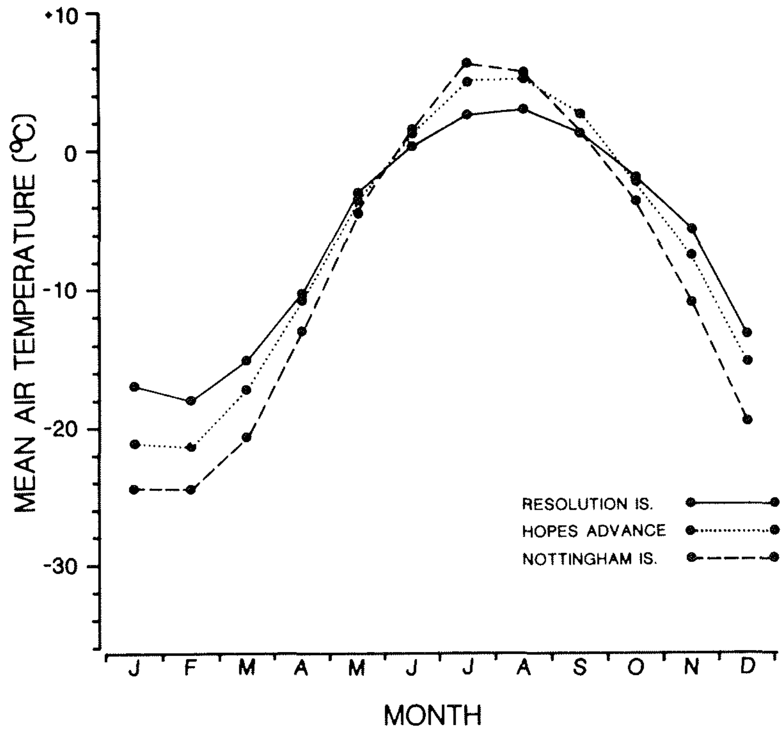

Figure 7. Mean monthly air temperature at Resolution Island, Cape Hopes Advance and Nottingham Island.

WIND

The Sailing Directions for Labrador and Hudson Bay (CANADIAN HYDROGRAPHIC SERVICE 1983) warns mariners that Hudson Strait is frequently subjected to storms, with the most intense striking the area between September and January. The calculated maximum gust speeds average 145-160 km/h (THOMAS 1953). The average frequency of gales at the eastern entrance is almost double that in the western Strait. At Resolution Island between October and March there are usually 3-4 days each month when winds exceed 60 km/h and between April and September fewer than two days per month (CANADIAN HYDROGRAPHIC SERVICE 1983). In contrast, at Nottingham Island between November and January there are usually fewer than 2 days per month with winds of more than 60 km/h, and from February to October usually one day or less per month.

The annual mean wind speed in the area is about 18-28 km/h (CANADIAN HYDROGRAPHIC SERVICE 1983) with the monthly mean speeds in winter tending to be 30-40% higher than in summer (DRINKWATER, 1986). There can be considerable variation from year to year. A difference in average wind strength exists between the eastern and western ends of the Strait (Fig. 8). At Resolution Island the annual mean wind speed is just over 27 km/h and at Cape Hopes Advance 28km/h, while in the western Strait at Nottingham Island it is only about 18 km/h. In midwinter (December to February) average monthly wind speeds at

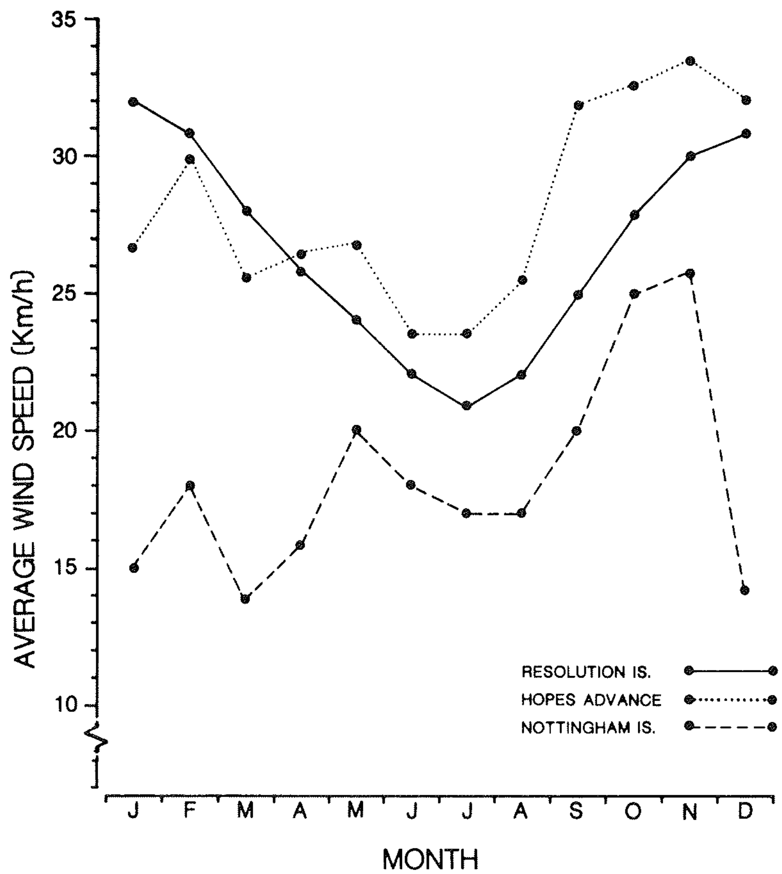

Figure 8. Mean monthly wind speed at Resolution Island, Cape Hopes Advance and Nottingham Island.

Resolution Island are twice as great as at Nottingham Island, while in summer (July to September) they are 25-30% higher in the eastern Strait than in the west. However, considerable caution is required in comparing weather data from the two areas in view of the fact that the Resolution Island station is located at 368 m above sea level, while the altitude of the Nottingham Island Station is only 16 m (R. BROWN, pers. comm.)

The wind direction in the Strait is also highly variable. However, there are certain seasonal patterns discernible, especially in the eastern and western regions. On average at Nottingham Island the prevailing winds are westerly during the summer, while at Resolution Island easterly and westerly winds generally occur with similar frequencies and strengths. Here, winds generally blow from the east or southeast 25-30% of time (DRINKWATER 1986). On the other hand, in the winter the winds are chiefly westerly and northwesterly in both regions. Channeling of the winds is evident all along the Strait but is particularly pronounced in the central region, between Cape Hopes Advance and Cap Nouvelle France, where the Strait narrows and there are high mountains along both coasts.

PRECIPITATION AND FOG

The proximity of the relatively open Labrador Sea and Davis Strait

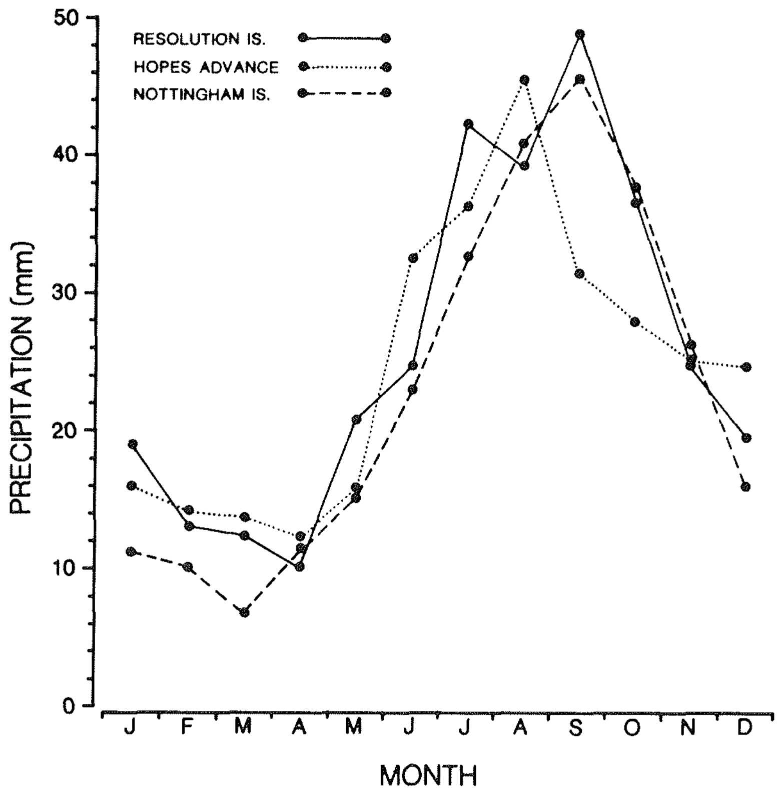

Figure 9. Mean monthly precipitation at Resolution Island, Cape Hopes Advance and Nottingham Island.

influences the precipitation in the Strait and again contributes to the establishment of a slight east-west gradient (Fig. 9). In the eastern Strait the mean annual precipitation is 380-500 mm/y. The amount declines westward to an average of about 250 mm in the vicinity of Foxe Channel (CAMPBELL 1958). About half of this precipitation falls as snow, mostly during autumn and spring rather than in midwinter. The first snow usually falls in late August or early September.

During May, the days lengthen rapidly, but the hours of bright sunshine actually decline because of a steadily increasing fog and cloud cover. This is largely associated with the rising air temperature and the expanding open water areas. For example, at Cape Hopes Advance the cloud cover rises from a yearly minimum of 5/10 cloud in February to a maximum of 8/10 in May. Considerable cloud cover persists throughout July and August. During the winter (November to April) the numbers of days with restricted visibility are comparable in both the eastern and western Strait (Fig. 10). After April the visibility deteriorates steadily in both areas with August being the month with the greatest amount of fog. However, at Resolution Island, the number of foggy days is almost double that at Nottingham Island. In fact, Resolution Island is reported to be one of the foggiest places in the Canadian Arctic (MAXWELL, 1981) and perhaps on earth (MARSH 1985) with fog on an average of one day in two. This is largely due to cold sea temperatures maintained by tidal mixing. The difference in the elevations of the two recording stations may also be a contributing factor.

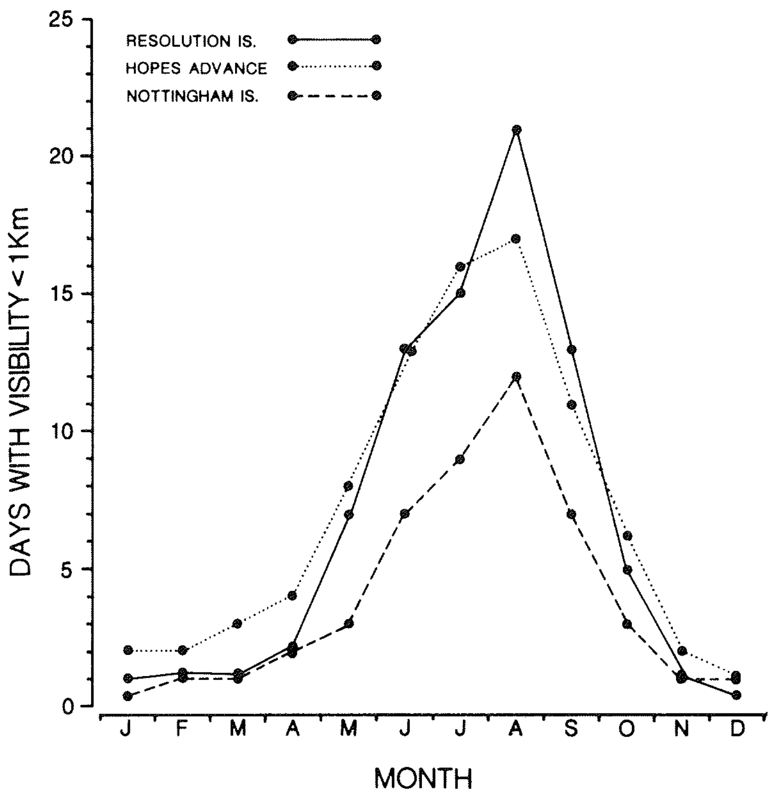

Figure 10. Days with visibility < 1 km during different months at Resolution Island, Cape Hopes Advance and Nottingham Island.

REFERENCES

ANDERSON, C. 1971. The flow of icebergs along the Canadian east coast. Pp. 52–61 *In*: **Proceedings of the Canadian Seminar on Icebergs**. Canada Department of National Defence.

BRYSON, R.A. & F.K. HARE. 1974. The climates of North America. Pp. 1–47. *In*: Bryson, R.A. and F.K. Hare (eds). **Climates of North America, World Survey of Climatology, Vol. II.** Elsevier, Amsterdam.

CAMPBELL, N.J. 1958. The oceanography of Hudson Strait. **Fish. Res. Board Can., MS Rep. Ser. (Oceanogr. Limnol.)** No. 12, 60 pp.

CANADIAN HYDROGRAPHIC SERVICE. 1983. **Sailing directions, Labrador and Hudson Bay. 5th edition**. Department of Fisheries and Oceans, Ottawa. 450 pp.

CATCHPOLE, A.J.W. & M.A. FAURER. 1983. Summer sea ice severity in Hudson Strait, 1751–1870. **Climatic Changes** 5:115–139.

CRANE, R.G. 1978. Seasonal variations of sea ice extent in the Davis Strait-Labrador Sea area and relationship with synoptic scale atmospheric circulation. **Arctic** 31:434–447.

DANIELSON, E.W. Jr. 1971. Hudson Bay ice conditions. **Arctic** 24:90–107.

DRINKWATER, K.F. 1986. Physical oceanography of Hudson Strait and Ungava Bay. Pp. 237–264 *In*: I.P. Martini (ed). **Canadian Inland Seas**. Elsevier Oceanography Series, 44, Elsevier, N.Y.

EBBESMEYER, C.C., A. OKUBO & J.M. HELSETH. 1980. Description of iceberg probability between Baffin Bay and the Grand Banks using a stochastic model. **Deep Sea Res.** 70:975–986.

FORWARD, C.N. 1956. Sea ice conditions along the Hudson Bay Route. **Geographical Bulletin** 8:22–50.

GASTON, A.J., D.K. CAIRNS, R.D.ELLIOT & D.G.NOBLE. 1985. A natural History of Digges Sound. **Can. Wildlife Serv. Rep. Ser.** No. 46, 63 pp.

LARDNER, M.M. 1968. The Ice. Pp. 318–341 *In*: Beals, C.S. (ed). **Science, History and Hudson Bay. Vol. 1.** Department of Energy, Mines and Resources, Ottawa.

MACLAREN, I.A. 1958. The biology of the ringed seal (*Phoca hispida* Schreber) in the eastern Canadian Arctic. **Bull. Fish. Res. Board Can.** 118, Ottawa. 97 pp.

McLEAN, N.B. 1929. **Report of the Hudson Strait expedition 1927-28.** King's Printer, Ottawa. 221 pp.

MARKHAM, W.E. 1988. **Ice Atlas Hudson Bay and Approaches**. Environment Canada, Atmospheric Environment Service, Ottawa. 123 pp.

MARSH, J.H. 1985. Hudson Strait. Pp. 843 *In*: Marsh, J.H. (ed) **Canadian Encyclopedia**. Hurtig Publishers, Edmonton.

MAXWELL, J.B. 1981. Climatic regions of the Canadian Arctic Islands. **Arctic** 34(3):225–240.

MONTGOMERY, M.R. 1949. Ice, open water and winter climate in the eastern Arctic of North America. Part II. The patterns of winter ice. **Arctic** 2(3):149–164.

STIRLING, I. 1981. Introduction. Pp. 5–6 In: Stirling, I. & H. Cleator (eds). **Polynyas in the Canadian Arctic**. Environment Canada, Can. Wildlife Serv. Occasional Paper 45, Edmonton, Alta.

THOMAS, M.K. 1953. **Climatological atlas of Canada**. Publication No. 3151, Division of Building Research, National Research Council and Meteorological Division, Department of Transport, Ottawa.

PHYSICAL AND CHEMICAL OCEANOGRAPHY

K. F. Drinkwater

Department of Fisheries and Oceans
Physical and Chemical Sciences Branch
Bedford Institute of Oceanography
Box 1006, Dartmouth, Nova Scotia, B2Y 4A2

INTRODUCTION

The purpose of this review is twofold; first, to provide a brief overview of the current state of knowledge of the physical and chemical oceanography of Hudson Strait and secondly, to indicate, in general terms, some of the major gaps in our knowledge. Unfortunately, little has been published on the chemical oceanography of the region, with the exception of some information on nutrient and oxygen distributions. As a consequence, this review focuses primarily upon the physical oceanography of the Strait. A recent overview of this subject was written by DRINKWATER (1986), which together with other review articles on Hudson Bay and Foxe Basin (MARTINI 1986) provided the then present day knowledge of these areas. This paper updates DRINKWATER (1986), most notably to include new work on low-frequency and seasonal variability of the currents.

Several physical oceanographic features combine to give the region its distinct characteristics. First, because it is located mainly above 60°N latitude and in the path of the polar air flow, the region is ice-covered for 8 months of the year. Second, resonance near the semi-diurnal tidal frequency results in high tidal elevations and strong tidal currents. These currents, in turn, produce intense vertical mixing that affects not only the vertical stratification of the water column and the temperature and salinity properties but also the surface nutrient concentrations and biological production. Third, the region receives large quantities of low salinity water from Hudson Bay and Foxe Basin as well as direct freshwater discharge from the rivers surrounding Ungava Bay. These contribute to the strong coastal currents along the southern coast of the Strait and around the shores of Ungava Bay. Physical processes within the Strait also have measurable effects on the physical and biological oceanographic distributions "downstream" on the Labrador Shelf.

SEA ICE AND ICEBERGS

The seasonal and interannual variability of sea ice distributions within Hudson Strait are relatively well known and have been described earlier in this volume by PERCY (1990). One important consequence of the extended period of sea-ice coverage is that during the period of maximum solar radiation (May to July), most of the heat is used to melt ice rather to heat the water. This contributes to the cold surface layer temperatures which persist even in summer.

Several questions pertaining to the ice budget in the Strait are still unanswered. For example, what quantity of the ice is formed locally and how much is imported? What is the fate of the sea-ice melt water? What role does the melt water play in the vertical stratification of the water column? How much of the melt water is transported out of the region on an annual basis?

Icebergs are also present in Hudson Strait. Generally they enter the Strait near Resolution Island, move northwestward along the coast of Baffin Island, and cross the Strait east of Big Island. They eventually exit the Strait north of Cape Chidley. The iceberg distributions have provided valuable information on the circulation patterns in the eastern entrance of the Strait, but icebergs are too few to significantly influence either the temperature and salinity characteristics of the water or the dynamics of the flow.

TIDES

The tides in Hudson Strait and Ungava Bay are primarily semi-diurnal (M_2 frequency, 12.42 h) and a response to forcing at the eastern entrance of the Strait by the North Atlantic tides. The M_2 tidal wave propagates from the Labrador Sea towards Hudson Bay rotating anticlockwise about a point near the northern tip of Labrador (Fig. 11). Part of the wave enters Ungava Bay and part continues to propagate westward through Hudson Strait. The tidal amplitude in Ungava Bay increases steadily from 3 m at the mouth to over 4.2 m at the head. The maximum observed sea-surface tidal amplitudes are 4.3 m in Leaf Basin. In Hudson Strait the M_2 tidal amplitude increases from 2 m at the eastern entrance to over 3.4 m near Big Island and then decreases to less than 2 m at the western entrance. The amplitudes on the Baffin Island side of the Strait are generally larger than those on the Quebec side. This difference is primarily related to the progressive nature of the tidal wave and the Coriolis effect arising from the earth's rotation (DRINKWATER 1988).

Numerical models of the barotropic tide (i.e. depth independent or vertically uniform response) show that current amplitudes for the M_2 constituent range from 1 to 2 m s^{-1} at the eastern and western ends of the Strait, 0.4 to 0.6 m s^{-1} in eastern Ungava Bay and 0.2 to 0.4 m s^{-1} throughout most of Hudson Strait (EASTON 1972; GRIFFITHS et al. 1981; CHANDLER et al. 1985). The model results show good agreement with available current meter measurements from FARQUHARSON & SAUER (1959), OSBORN et al. (1978) and DRINKWATER (1983). The current measurements have also confirmed the barotropic nature of the tides and a large spring-neap cycle (DRINKWATER 1988).

The effect on the tidal currents of friction at the seabed or the underside of ice cover results in shear-induced turbulence and, where the currents are of high magnitude, can cause intense vertical mixing. Surface generated turbulence during winter in the presence of ice cover does occur in other subarctic and arctic areas (PRINSENBERG & BENNETT 1989) and may be of importance in Hudson Strait. No measurements of this effect in the Strait have been obtained, however. More is known about the influence of bottom generated turbulence whose importance was first suggested by ISELIN (1927) and later by DUNBAR (1951) and CAMPBELL (1958). GRIFFITHS et al. (1981) predicted the location of tidal fronts in Hudson Strait, Ungava Bay, Hudson Bay and Foxe Basin from a numerical tidal model and using the h/u^3 criteria, a stratification parameter devised by SIMPSON & HUNTER (1974) where h is the depth of the water column and u is the average tidal speed. GRIFFITHS et al. (1981) identified large areas of Ungava Bay, eastern Foxe Basin and both the eastern and western entrances of Hudson Strait as containing tidally well-mixed waters. Hydrographic data has confirmed their model predictions (DRINKWATER & JONES 1987; TAGGART et al. 1989). High surface nutrient and chlorophyll a concentrations were also found in the vicinity of

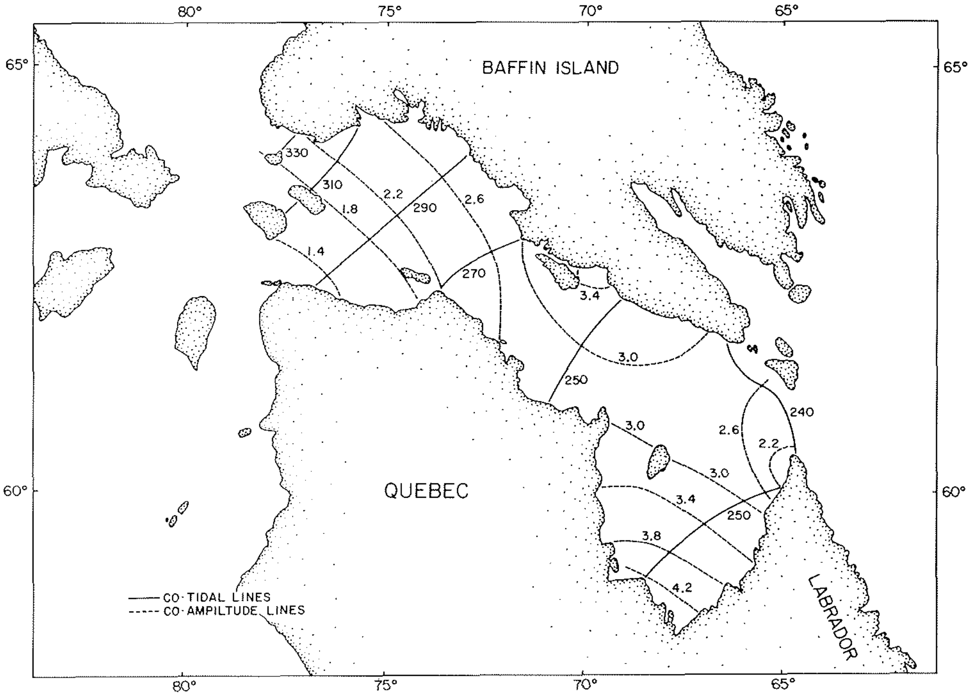

Figure 11. The coamplitude and cophase lines for the surface M_2 tidal wave in Hudson Strait and Ungava Bay (from CHANDLER *et al.* 1985). The coamplitude lines (in m) indicate the sea surface tidal elevation amplitudes and the cophase lines indicate the time of high water in degrees relative to GMT + 4h (EST).

these well-mixed waters during the summer, in contrast to the low values found in the stratified regions of the Strait (DRINKWATER & JONES 1987). The tidally well-mixed waters at the eastern and western ends of Hudson Strait are unique, extending in certain locations to depths greater than 200 m. They also differ from most other tidally-mixed regions in that the horizontal density differences across the tidal fronts are salinity controlled, with the cross-front temperature gradients being relatively weak.

Physical oceanographers have a relatively good first-order description and understanding of the tides and tidal processes in Hudson Strait and Ungava Bay. One gap in our knowledge, however, is the response to the tidal flow over the sill near the eastern end of the Strait. Theory would predict the generation of internal tidal waves. CAMPBELL (1958) had earlier speculated upon their existence and possible importance as a mechanism for vertical mixing. Another gap is our lack of knowledge of the tidally-induced residual circulation. This circulation pattern could be explored using existing numerical models.

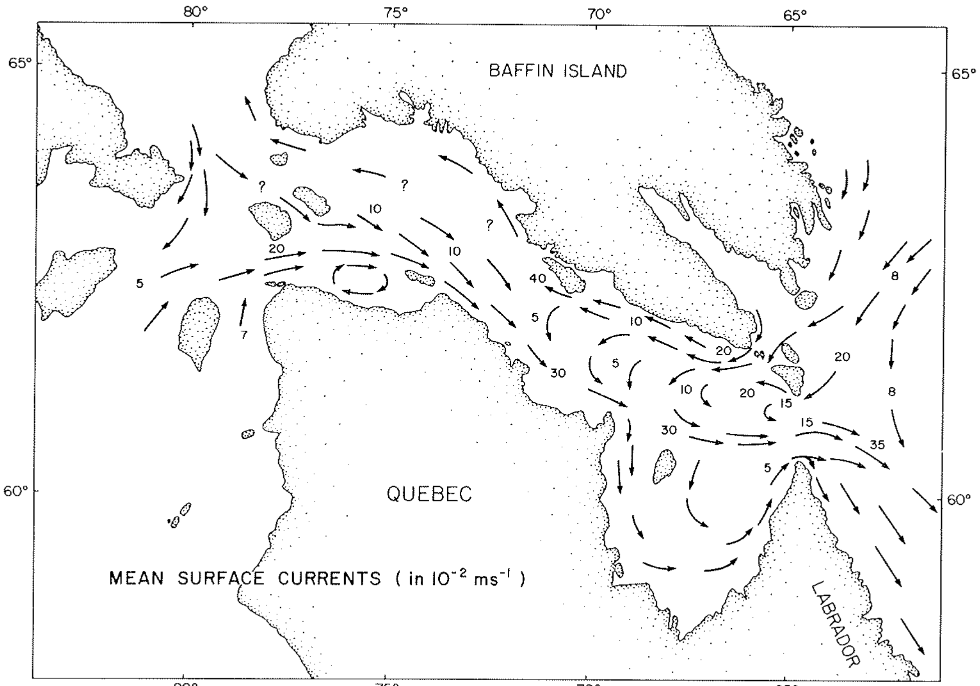

Figure 12. The surface circulation pattern in Hudson Strait and Ungava Bay during the summer.

RESIDUAL CURRENTS

The residual circulation pattern in Hudson Strait is dominated by three features; (1) an intense nearshore coastal current that flows southeastward along the Quebec shore and eventually exits the Strait north of Cape Chidley, (2) a weaker, broader current flowing northwestward on the Baffin Island side of the Strait, and (3) a strong southward cross-channel flow in the eastern half of the Strait (Fig. 12). In Ungava Bay, the flow is principally cyclonic (SMITH 1931; DUNBAR 1958). These current patterns have been determined from observations of ice and iceberg drift, temperature and salinity distributions, satellite-tracked buoys, and moored current meter information (See DRINKWATER 1986 for a detailed review of the observations). The coastal current off Quebec has an offshore length scale of the order of the internal Rossby radius which is approximately 10 km (DRINKWATER 1988). This current also exhibits a strong vertical shear with the magnitude decreasing by a factor of 10 between 30 and 200 m (DRINKWATER 1988). Elsewhere in the Strait the vertical decrease in the magnitude of the currents is much less, generally being a factor of less than 3 (LEBLOND *et al.* 1981; DRINKWATER 1988).

DRINKWATER (1988) calculated the mean along-channel volume transports in central Hudson Strait from moored current meter data collected during August to October, 1982. The mean transports were $0.9 \pm 0.2 \times 10^6$ m^3 s^{-1} to the southeast on the Quebec side and $0.8 \pm 0.2 \times 10^6$ m^3 s^{-1} to the northwest on the Baffin

Island side. These matched closely the transport estimates based on geostrophy using hydrographic data gathered in August, 1982, (DRINKWATER 1988) and from current meter data collected in August-September of 1959 by FARQUHARSON & SAUER (1960). The difference between these mean flows is the net transport. It is 0.1 x 10^6 m^3 s^{-1} to the southeast (seaward) and is close to that expected based on the estimated net transport into Foxe Basin through Fury and Hecla Strait plus the annual freshwater discharge into Hudson Bay (DRINKWATER 1988). The net transport is, however, smaller than the uncertainties in the components from which it was calculated and therefore not statistically significant.

Moored current meter data collected in the southeastward flowing coastal current between October, 1986, and August, 1987 have shown that the residual currents and transports vary seasonally (DRINKWATER, unpublished data). The data were obtained near Wales Island (just to the north of Wakeham Bay) and consisted of current meters located at 40 and 100 m at an inshore site (15 km from the coast) and at 40 and 200 m at an offshore site (25 km from the coast). The maximum monthly mean currents at 40 m exceeded 0.5 m s^{-1} in October and November at the inshore station and 0.4 m s^{-1} in November at the offshore station. Relatively weak monthly mean currents occurred between January and July, fluctuating within the range of 0.15-0.25 m s^{-1} at the inshore site and 0.1-0.2 m s^{-1} at the offshore site. The mean currents at 100 and 200 m were less than 0.1 m s^{-1} during all months with the maxima occurring in October-November. An accurate determination of the volume transport can not be obtained from this data set because of its lack of spatial resolution. However, based on comparison of current speeds, the maximum southeastward transport in October-November may be nearly double that estimated by DRINKWATER (1988).

The importance of the Hudson Bay river runoff as a forcing mechanism for the southeastward flowing coastal current off Quebec was recognized early by ISELIN (1927), HACHEY (1931), SMITH *et al.* (1937) and CAMPBELL (1958). ISELIN (1927) speculated that the outflow results from a rise in sea level in Hudson Bay due to the addition of freshwater from river runoff. Density differences between the low salinity waters in Hudson Bay and Foxe Basin and the high salinity waters in the Labrador Sea also produces an along-channel pressure gradient that would provide a driving force for the Hudson Strait outflow.

The northwestward current in Hudson Strait is a continuation of the southward flowing Baffin Land Current (ISELIN 1927). The baroclinic component of this flow is confined within an internal Rossby radius of shore (approximately 10 - 20 km). As the width of Hudson Strait is several times the internal Rossby radius, it can accommodate both this inflowing current and the southeastward flow near the Quebec shore (Fig. 12) without interference between them (LEBLOND 1980; CHERNIAWSKY & LEBLOND 1987). Several forcing mechanisms for the cross-channel flow in the eastern end of the Strait have been examined using theoretical models. These include the influence of topographic shoaling on the barotropic flow (SANDERSON & LEBLOND 1984) and the interaction of the baroclinic flows into and out of Hudson Strait (CHERNIAWSKY & LEBLOND 1986, 1987). However, neither mechanism can explain the observed recirculation.

Future studies should include further modeling of the dynamics of the residual currents, especially the southwestward coastal current and the cross-channel flow in the eastern end of Hudson Strait. In addition, reliable quantitative estimates of the volume transport at both entrances of the Strait will be needed for any future budget studies, such as for heat, salt, nutrients, etc. Other gaps in our knowledge include the relative importance of the volume transports originating from Hudson Bay and Foxe Basin (see PRINSENBERG (1986a, b) for a description of our present understanding) and the circulation in the northwestern corner of Hudson Strait.

LOW FREQUENCY CURRENT VARIABILITY

Current fluctuations at periods of 1-10 d were evident in early current meter records obtained in Hudson Strait (FARQUHARSON & SAUER 1960; LEBLOND *et al.* 1981; DRINKWATER 1983). A possible generating mechanism was discussed by Wright *et al.* (1987). Results from a theoretical model suggested that water is forced in and out through Hudson Strait as Hudson Bay adjusts isostatically to fluctuating atmospheric pressure. For example, when there is a high pressure system over Hudson Bay, the sea level elevations in the Bay are depressed, the excess water having been pushed out through Hudson Strait. The maximum response was considered to occur at periods of 2-6 d corresponding to the peak in the energy of the atmospheric pressure forcing. The model also predicted that the associated flow across the Labrador Shelf outside the eastern entrance to Hudson Strait would generate shelf waves. These would propagate down the shelf, thereby affecting the sea level response along the Labrador coast. The model results were supported by a statistical analysis that showed a significant relationship between sea level fluctuations at Nain on the Labrador coast and atmospheric pressure variability over Hudson Bay.

DRINKWATER (1990) analyzed current meter data collected in 1982 for evidence of low-frequency variability (periods 1-10d). Four current meter stations were located across the Strait between Cape Hopes Advance and Baffin Isand and an additional site was located 90 km to the east in mid-channel. At the site nearest the Quebec coast (within 10 km) the low-frequency currents had r.m.s. (root-mean-square) speeds of 0.1 m s^{-1}, exhibited strong vertical coherence throughout the water column (200 m), were in phase, and decreased only slightly with depth. Statistical analysis showed that these barotropic fluctuations were primarily controlled by air pressure fluctuations over Hudson Bay as had been suggested by WRIGHT *et al.* (1987), with direct wind forcing within the Strait of secondary importance. The maximum response was at periods of 3-7 d, similar to those predicted by Wright *et al.* (1987). In contrast, at the remaining sites, the low-frequency currents were weak with typical r.m.s. speeds of less than 0.05 m s^{-1}. They were an order of magnitude less than the tidal currents and less than, or comparable to, the mean currents. These currents were not coherent over vertical and horizontal scales as small as 30 m and 20 km, respectively, and they were unrelated to air pressure fluctuations over Hudson Strait or local wind forcing.

Additional current records are required to determine the relative importance of low-frequency currents and their forcing mechanisms in other areas of Hudson Strait, especially near the two entrances and in Ungava Bay.

TEMPERATURE AND SALINITY CHARACTERISTICS

The main feature of the observed horizontal distribution of near surface temperature and salinity is the marked across-channel gradient over most of the Strait with higher temperatures and lower salinities to the south. These reflect the influence of the outflow from Hudson Bay. Surface temperatures on the south side of the Strait range from 0^{o} to $5^{o}C$ during the ice-free season and salinities typically vary from 29 to 32^{o} ppt. although much lower values have been observed in the vicinity of melting ice. On the north side of the Strait, surface temperatures generally range from 0^{o} to $2^{o}C$ during the ice-free season while surface salinities are 32 to 33^{o} ppt.

In the vicinity of Resolution Island, tidally-generated mixing of the waters entering the Strait from the Baffin Island Shelf produces a nearly homogeneous water mass over the upper 200 to 300 m. This water is characterized by relatively high salinity ($>33^{o}$ ppt.) and low temperature ($<1^{o}C$). Part of this water mass is advected by the residual circulation across the Strait and eventually mixes with the low salinity waters flowing seawards. The remainder is carried northwestward which, in part, accounts for the small vertical gradients in temperature and salinity found off Baffin Island.

The water mass below 100 m on the south side of the Strait was classified as polar water by Dunbar (1951) with temperatures $< -1^{o}C$ and salinities between 33 and 33.5^{o} ppt. This water originates principally in Foxe Basin and is formed during the winter by salt rejection during ice growth (PRINSENBERG 1986b). It undergoes only slight changes in its temperature and salinity characteristics as it flows seaward, until it reaches the eastern entrance to Hudson Strait. There, intense vertical mixing all but eliminates its distinctive characteristics. In western Hudson Strait the layers below 200 m are almost exclusively composed of polar water. This contrasts with eastern Hudson Strait where the deep waters are relatively warm ($2^{o}C$) and saline (34^{o} ppt.) which reflects the influence of Labrador Sea water.

The convergence and intense mixing at the eastern entrance of Hudson Strait of water from off the Baffin Island Shelf, the low salinity outflow from Hudson Bay and Foxe Basin, and offshore Labrador Sea water produces a new distinct water mass (SMITH *et al.* 1937, DUNBAR 1951). This water is carried by the residual currents onto the Labrador Shelf, which lead KOLLMEYER *et al.* (1967) to call eastern Hudson Strait the "birthplace" of Labrador Shelf water.

Wintertime temperature and salinity data within Hudson Strait are scarce. Some data are available from current moorings deployed during October, 1986, to August, 1987 (MYERS *et al.* 1990). They show a salinity minimum at 40 m in November-December and, from measurements at other subarctic sites, MYERS *et al.* (1990) suggested that the surface salinity minimum in Hudson Strait likely occurs in October. The observed minimum is thought to be related to the influence of the freshwater discharge into Hudson Bay, based on river discharge, salinity, and current data from Hudson Bay (MYERS *et al.* 1990). This had also been suggested by SUTCLIFFE *et al.* (1983) but they estimated that the salinity minimum would occur in August. They had not considered the travel time of the river discharge induced low salinity water within Hudson Bay.

Future work should include a detailed T,S analysis in order to quantify mixing rates and to better identify the origin of the water masses within Hudson Strait and Ungava Bay. The first such analyses were carried out by DUNBAR (1951) and CAMPBELL (1958) from bottle data. Much more data collected with CTD (Conductivity-Temperature-Depth) profilers are now available. HUDON (1990) has examined some of these data but more extensive investigation should be undertaken. Additional hydrographic measurements are needed in winter, especially near surface, to determine the seasonal variability in temperature and salinity. There is also a paucity of hydrographic data in Ungava Bay, even in summer.

DISSOLVED OXYGEN AND NUTRIENT DISTRIBUTIONS

CAMPBELL (1958) found seasonal variability in dissolved oxygen concentrations in Hudson Strait from cruises in June and October of 1955 and in July of 1956. High concentrations in the near surface layers in June and July, with values at or above saturation levels, were attributed to the presence of phytoplankton and cool waters. A marked decrease in O_2 levels was observed in October and was believed due to reduced phytoplankton activity and warmer waters. Some persistent spatial gradients in O_2 were also observed. In particular, high concentrations were observed on the Baffin Island side of the Strait while lower values were found on the Quebec side. The latter are associated with the low salinity Hudson Bay outflow (CAMPBELL 1958).

Nutrient concentrations within the Strait, as in most oceanic regions, increase with depth (KOLLMEYER *et al.* 1967). The concentrations below approximately 100 m show only small differences throughout the Strait, these differences depending upon the source of the deep waters. Near-surface nutrient distributions in late summer are principally controlled by tidal mixing. DRINKWATER & JONES (1987) found that where mixing reduced vertical stability of the water column, surface nutrients were high. Integrated nitrate over the top 20 m were maximum (> 1 ug-at l^{-1}) at both entrances to the Strait with the highest values (> 5 ug-at l^{-1}) in Gabriel Strait. In contrast, where the water was stratified, surface layer nitrates were low or undetectable which is believed to reflect utilization by primary producers. Phosphate and silicate distributional patterns were similar to those of nitrate.

Observations have shown that the high concentration of surface nutrients at the eastern entrance to the Strait are transported by the residual currents onto the northern Labrador Shelf (KOLLMEYER *et al.* 1967, SUTCLIFFE *et al.* 1983). This nutrient flux is believed to initiate a food chain, thereby influencing both the biological production and its distribution on the Labrador Shelf (SUTCLIFFE *et al.* 1983).

CONCLUDING REMARKS

A first order description of the tides, ice distributions, circulation patterns and water mass characteristics is available for much of Hudson Strait. The tides are particularly important, dominating the current spectra, generating intense vertical mixing, and causing reduced stratification at both entrances to the Strait and in Ungava Bay. High surface nutrient concentrations are associated with these tidally-induced mixed regions. Another significant influence on the physical oceanography of Hudson Strait is the low salinity outflow from Hudson Bay and Foxe Basin. Much is yet to be done to improve our knowledge of the oceanography of the region, in particular, theoretical studies, numerical modeling, and the collection of additional moored current meter data, especially in the western half of Hudson Strait and Ungava Bay. Some of the major gaps have been identified within the review.

I end this review by returning to the subject of chemical oceanography. Chemical techniques offer great potential to answer several basic questions on the oceanography of Hudson Strait. For example, investigations of trace metals and other chemical constituents could help in tracking water masses and determining mixing rates of the water. Also, oxygen isotope ratios (δO^{18}) could provide improved knowledge of the fate of ice-melt water and freshwater discharge within the Strait and Ungava Bay. These are but just two examples. Hopefully, these and other chemical oceanographic studies will be undertaken within Hudson Strait in the near future.

ACKNOWLEDGEMENTS

I thank S. Prinsenberg, P. Jones, and P. Larouche for comments on an earlier version of this manuscript.

REFERENCES

CAMPBELL N.J. 1958. The oceanography of Hudson Strait. **Fish. Res. Board Can. MS Rep. Ser. (Oceanogr. Limnol.)** 12, 60 pp.

CHANDLER, P.C.P., S. DE MARGERIE & J.D. COVILL. 1985. Numerical modelling of tides in Hudson Strait and Ungava Bay. **Can. Contract Rep. Hydrogr. Ocean Sci.** 13. 60 pp.

CHERNIAWSKY, J. & P.H. LEBLOND. 1986. Rotating flows along indented coastlines. **J. Fluid Mech.** 169:379-407.

CHERNIAWSKY, J. & P.H. LEBLOND. 1987. The baroclinic circulation in Hudson Strait. **Atmosphere-Ocean** 25:416-426.

DRINKWATER, K.F. 1983. Moored current meter data from Hudson Strait, 1982. **Can. Data Rep. Fish. Aquat. Sci.** 381. 46 pp.

DRINKWATER, K.F. 1986. Physical oceanography of Hudson Strait and Ungava Bay. Pp. 237-264 *In*: Martini, I.P. (ed). **Canadian Inland Seas.** Elsevier, Amsterdam.

DRINKWATER, K.F. 1988. On the mean and tidal currents in Hudson Strait. **Atmosphere-Ocean** 26:252-266.

DRINKWATER, K.F. 1990. Low-frequency current variability in Hudson Strait. (in preparation).

DRINKWATER, K.F. & E.P. JONES. 1987. Density stratification, nutrient and chlorophyll distributions in the Hudson Strait region during the summer and their relation to tidal mixing. **Cont. Shelf Res.** 7:599-607.

DUNBAR, M.J. 1951. Eastern Arctic waters. **Bull. Fish. Res. Board Can.** 88. 131 pp.

DUNBAR, M.J. 1958. Physical oceanographic results of the "Calanus" expedition in Ungava Bay, Frobisher Bay, Cumberland Sound, Hudson Strait and northern Hudson Bay, 1945-1955. **J. Fish. Res. Board Can.** 15:155-201.

EASTON, A.K. 1972. Tides of Hudson Strait. **Bedford Institute Oceanographic Rep. Ser.**, BI-R-72-6. 14 pp.

FARQUHARSON, W.I. & C.D. SAUER. 1959. Tidal and oceanographic survey, Hudson Strait, August and September 1959. **Data Record, Canadian Hydrogr. Serv.**, Dept. Mines and Tech. Surveys, Ottawa, Ont..55 pp.

FARQUHARSON, W.I. & C.D. SAUER. 1960. Tidal and oceanographic survey of a section of Hudson Strait, August and September 1959. **Prelim. Rep. Canadian Hydrogr. Serv.**, Dept. Mines and Tech. Surveys, Ottawa, Ont.. 41 pp.

GRIFFITHS, D.K., R.D. PINGREE & M. SINCLAIR. 1981. Summer tidal fronts in the near arctic regions of Foxe Basin and Hudson Bay. **Deep-Sea Res.** 28:865-873.

HACHEY, H.B. 1931. Biological and oceanographic conditions in Hudson Bay. 6. The general hydrography and hydrodynamics of the waters in the Hudson Bay region. **Contr. Can. Biol. Fish.** 7:91-118.

HUDON, C. 1990. Distribution of shrimp and fish by-catch assemblages in the Canadian Eastern Arctic in relation to water circulation. **Can. J. Fish. Aquat. Sci.** 47:1710-1723.

ISELIN, C.O. 1927. A study of the northern part of the Labrador Current. **Bull. Nat. Res. Council**, Nat. Acad. Sci., Washington, D.C. 61:217-222.

KOLLMEYER, R.C., D.S. MCGILL & N. CORWIN. 1967. Oceanography of the Labrador Sea in the vicinity of Hudson Strait in 1965. **U.S. Coast Guard Oceanogr. Rep.** No. CG 373-12. 34 pp.

LEBLOND, P.H. 1980. On the surface circulation in some channels of the Canadian Arctic archipelago. **Arctic** 33:189-197.

LEBLOND, P.H., T.R. OSBORN, D.O. HODGINS, R. GOODMAN & M. METGE. 1981. Surface circulation in the western Labrador Sea. **Deep-Sea Res.** 28:683-693.

MARTINI, I.P. 1986. **Canadian Inland Seas.** Elsevier Oceanography Series 44, Elsevier, Amsterdam. 494 p.

MYERS, R.A., S.A. AKENHEAD & K.F. DRINKWATER. 1990. The influence of Hudson Bay Runoff and Ice-melt on the salinity of the inner Newfoundland Shelf. **Atmosphere-Ocean.** (in press).

OSBORN, T.R., P.H. LEBLOND & D.O. HODGINS. 1978. Analysis of ocean currents. Davis Strait-1977, Volume 1. **APOA Rep.** 138, Arctic Petroleum Operators Association, Calgary, Alberta. 264 pp.

PERCY, J. 1990. Ice conditions and climate. Pp. 78-86 *In:* Percy, J.A. (ed). Proceedings of a workshop: Marine Ecosystem Studies in Hudson Strait, Nov. 9-10, 1989, Montreal, Quebec. **Can. Tech. Rep. Fish. Aquat. Sci.** No. 1770.

PRINSENBERG, S. 1986a. The circulation pattern and current structure of Hudson Bay. Pp. 187-204 *In*: Martini I.P. (ed). **Canadian Inland Seas**. Elsevier, Amsterdam.

PRINSENBERG, S. 1986b. On the physical oceanography of Foxe Basin. Pp. 217-236 *In*: Martini I.P. (ed). **Canadian Inland Seas**. Elsevier, Amsterdam.

PRINSENBERG, S.J. & E.B. BENNETT. 1989. Vertical variations of tidal currents in shallow landfast ice-covered regions. **J. Phys. Oceanogr.** 19: 1268-1278.

SANDERSON, B.G. & P.H. LEBLOND. 1984. The cross-channel flow at the entrance of Lancaster Sound. **Atmosphere-Ocean** 22: 484-497.

SIMPSON, J.H. & J.R. HUNTER. 1974. Fronts in the Irish Sea. **Nature** 250:404-406.

SMITH, E.H. 1931. The Marion Expedition to Davis Strait and Baffin Bay, 1928. **U.S. Coast Guard Bull.** No. 19, Part 3. 221 pp.

SMITH, E.H., F.M. SOULE, & O. MOSBY. 1937. The Marion and General Greene Expeditions to Davis Strait and Baffin Bay. **U.S. Coast Guard Bull.** No. 19, Part 2. 259 pp.

SUTCLIFFE, W.H. JR, R.H. LOUCKS, K.F. DRINKWATER & A.R. COOTE. 1983. Nutrient flux onto the Labrador Shelf from Hudson Strait and its biological consequences. **Can. J. Fish. Aquat. Sci.** 40:1692-1701.

TAGGART, C.T., K.F. DRINKWATER, K.T. FRANK, J. MCRUER, & P. LAROUCHE. 1989. Larval fish, zooplankton community structure, and physical dynamics at a tidal front. **Rapp. P.-v. Réun. Cons. int. Explor. Mer** 191:184-194.

WRIGHT, D.G., D.A. GREENBERG, & F.G. MAJAESS. 1987. The influence of bays on adjusted sea level over adjacent shelves with application to the Labrador Shelf. **J. Geophy. Res.** 92:14610-14620.

PRIMARY PRODUCTION

H. Welch

Department of Fisheries and Oceans
Freshwater Institute
501 University Crescent
Winnipeg, Manitoba, R3T 2N6

There are no published measurements of primary production within Hudson Strait. The nearest measurements are from Frobisher Bay (GRAINGER 1979), the Belcher Islands (GRAINGER 1982), northern Foxe Basin (IRWIN *et al.* 1983), the Labrador Sea (IRWIN *et al.* 1980 and others), and Ungava Bay (IRWIN *et al.* 1982). Ice algal productivity has been studied extensively in southeastern Hudson Bay (GOSSELIN *et al.* 1985; GOSSELIN *et al.* 1986; ROCHET *et al.* 1986; MAESTRINI *et al.* 1986; LEGENDRE *et al.* 1987), and for one season in northwestern Hudson Bay (WELCH *et al.* in prep.). In addition, the seston and chlorophyll ecology of Hudson Bay has been studied (ANDERSON & ROFF 1980), and there is chlorophyll data for Hudson Bay collected 19 August-7 September 1982 (DRINKWATER & JONES 1987). Accordingly the purpose of this brief review will be to conclude what we can, based upon studies from other areas, combined with our knowledge of the oceanography of Hudson Strait.

The broad outlines of Hudson Strait and Hudson Bay physical oceanography are known (DRINKWATER & JONES 1987; CAMPBELL 1958; DUNBAR 1951), but very little chemical data has been collected in either area (GRAINGER 1982; DRINKWATER & JONES 1987). Hudson Strait is a relatively deep east-west channel somewhat similar to Barrow Strait to the north and the Gulf of St. Lawrence to the south. The net outflow of water eastward is small, derived from runoff around Hudson Bay and the southward flow of arctic water through Fury and Hecla Strait. Tidal currents flow westward into the Strait and out eastward on the south side of the Strait. Tides are very high and currents are sometimes strong. Islands at either end of the Strait act as choke points where deep, nutrient-rich water is mixed into surface water. We can expect, therefore, that the concentration of the limiting nutrient, nitrogen, is relatively high in the well-mixed areas, and that chlorophyll is high as a result. What little data exists for nitrate and chlorophyll suggests that this is true. Depth-integrated values over the top 20 m for nitrate in August 1982 were in the 2-5 mg m^{-3} range around Resolution Island to the east end of the Strait and 1-3 mg m^{-3} around Nottingham Island to the west. At the same time, chlorophyll concentrations at 0-20 m generally exceeded 1 mg m^{-3} only in the same well-mixed areas. Chlorophyll concentrations were otherwise mostly less than 1 mg m^{-3} throughout the rest of the Strait. At the beginning of the phytoplankton photosynthetic season, coinciding with break-up in early July, Hudson Strait probably has high nutrient concentrations throughout the water column, which in turn must result in an early phytoplankton bloom; but no oceanographic observations have been made before late summer.

Primary productivity in Hudson Strait is expected to be higher than for the main body of Hudson Bay to the west, where all measurements to date have indicated low nutrient concentrations, low productivity, and uniformly low chlorophyll in offshore surface waters (GRAINGER 1982; ANDERSON & ROFF 1980).

This is a result of stratification of surface waters due to ice melt and runoff (PRINSENBERG 1988), with very little vertical mixing occurring after break-up. Thus Hudson Strait may be a photosynthetic "hot spot" relative to the more stable, stratified waters to the west and east. It has been proposed (SUTCLIFFE *et al.* 1983) that Hudson Strait may thus serve as a "pump" for nutrients, injecting inorganic nitrogen into surface waters where turbulence is high, and exporting primary production and nutrients south along the Labrador coast.

Hudson Strait is covered almost entirely by unconsolidated, mobile, floe ice by midwinter. Only a relatively narrow strip is shore-fast ice. Recent work (WELCH *et al.* in prep.; WELCH & BERGMANN 1989) has shown that the growth of ice algal biomass in spring is a predictive function of cumulative surface light and snow cover, provided nitrate is not limiting. Since this relationship holds for both Barrow Strait (75°N) and the northwest coast of Hudson Bay (63°N) (WELCH & BERGMANN 1989), and since nitrate is probably high in late winter over the deep waters of Hudson Strait, we can expect considerable production of ice algae in April and May. While this algal production may average only a few grams of carbon per square meter (depending upon snow cover), it is probably an important early-season food source for zooplankters such as *Pseudocalanus minutus* which are adapted to using it (RUNGE & INGRAM 1988; CONOVER *et al.* 1986). Very high biomass of sympagic ("with the ice") amphipods are also associated with ice algae over shallow water elsewhere in the arctic (PIKE & WELCH 1990; SIFERD *et al.* in prep.) but given the mean depth of Hudson Strait, we can expect sympagic amphipods to be of little importance to the main, deeper body of water. They may, however, be important to the spring feeding ecology of diving sea birds, as they are elsewhere in the arctic (BRADSTREET & CROSS 1982).

Benthic algae, particularly macrophytic kelps, are undoubtedly important primary producers in the shallow waters of Hudson Bay (pers. obs.), but given the average depth of Hudson Strait, macrophyte production can only be important over the relatively small area of shoals found along shores and around islands. In those locations they may contribute to specific benthic detritus food chains that are partly independant of pelagic photosynthesis. Remote sensing of snow, ice and chlorophyll would be most useful for determining the patterns of ice algal and phytoplanktonic primary production. Combined with photosynthetic parameters derived from photosynthesis/irradiance curves (e.g. FEE 1984), quite accurate seasonal pictures of phytoplankton production may be drawn.

REFERENCES

ANDERSON, J.T. & J.C. ROFF. 1980. Seston ecology of the surface waters of Hudson Bay. **Can. J. Fish. Aquat. Sci.** 37: 2242-2253.

BRADSTREET, M.S.W. & W.E. CROSS. 1982. Trophic relationships at high arctic ice edges. **Arctic** 35: 1-12.

CAMPBELL, N.J. 1958. The oceanography of Hudson Strait. **Fish. Res. Board Can. MS. Rep. Ser. (Oceanogr. Limnol.)** 12. 60 pp.

CONOVER, R.J., A.W. HERMAN, S.J. PRINSENBERG, & L.R. HARRIS. 1986. Distribution and feeding by the copepod *Pseudocalanus* under fast ice during the arctic spring. **Science** 232: 1245-1247.

DRINKWATER, K.F. & E.P. JONES. 1987. Density stratification, nutrient and chlorophyll distributions in the Hudson Strait region during summer and their relation to tidal mixing. **Cont. Shelf Res.** 7: 599-607.

DUNBAR, M.J. 1951. Eastern Arctic Waters. **Bull. Fish. Res. Board Can.** 88. 131 pp.

FEE, E.J. 1984. Freshwater Institute primary production model user's guide. **Can. Tech. Rep. Fish. Aquat. Sci.** 1328. v + 36 pp.

GOSSELIN, M., L. LEGENDRE, S. DEMERS, & R.G. INGRAM. 1985. Responses of sea-ice microalgae to climatic and fortnightly tidal energy inputs (Manitounuk Sound, Hudson Bay). **Can. J. Fish. Aquat. Sci.** 42:999-1006.

GOSSELIN, M., L. LEGENDRE, J.-C. THERRIAULT, S. DEMERS, & M. ROCHET. 1986. Physical control of the horizontal patchiness of sea-ice microalgae. **Mar. Ecol. Prog. Ser.** 29:289-298.

GRAINGER, E.H. 1979. Primary production in Frobisher Bay, Arctic Canada. Pp. 161-266. *In*: Billingsley, L.W. and T.W.M. Cameron (eds) **Energy flow--its biological dimensions. A summary of the IBP in Canada**, 1964-1974. Can. Comm. for the IBP. Royal Soc. Can.

GRAINGER, E.H. 1982. Factors affecting phytoplankton stocks and primary productivity at the Belcher Islands, Hudson Bay. **Naturaliste can. (Rev. Ecol. Syst.)** 109:787-791.

IRWIN, B., L. HARRIS, M. HODGSON, E. HORNE & T. PLATT. 1983. Primary productivity and nutrient measurements in northern Foxe Basin N.W.T., from 27 August to 7 September, 1981. **Can. Data Rep. Fish. Aquat. Sci.** 385. 40 pp.

IRWIN, B., W.G. HARRISON, C.L. GALLEGOS, & T. PLATT. 1980. Phytoplankton productivity experiments and nutrient measurements in the Labrador Sea, Davis Strait, Baffin Bay and Lancaster Sound from 26 August to 14 September 1978. **Fish. Mar. Serv. Data Rep.** 213. 103 pp.

IRWIN, B., T. PLATT, W.G. HARRISON, C.L. GALLEGOS, & P. LINDLEY. 1982. Phytoplankton productivity experiments and nutrient measurements in Ungava Bay NWT from August 1 to September 3, 1979. **Can. Data Rep. Fish. Aquat. Sci.** 287. 208 pp.

LEGENDRE, L., S. DEMERS, & M. GOSSELIN. 1987. Chlorophyll and photosynthetic efficiency of size-fractionated sea-ice microalgae (Hudson Bay, Canadian Arctic). **Mar. Ecol. Prog. Ser.** 40:199-203.

MAESTRINI, S.Y., M. ROCHET, L. LEGENDRE, & S. DEMERS. 1986. Nutrient limitation of the bottom-ice microalgal biomass (southeastern Hudson Bay, Canadian Arctic). **Limnol. Oceanogr.** 31:969-982.

PIKE, D.G. & H.E. WELCH. 1990. Spatial and temporal distribution of the sub-ice macrofauna in the Barrow Strait area, Northwest Territories. **Can. J. Fish. Aquat. Sci.** 47(1):81-91.

PRINSENBERG, S.J. 1988. Ice-cover and ice-ridge contributions to the freshwater contents of Hudson Bay and Foxe Basin. **Arctic** 41:6-11.

ROCHET, M., L. LEGENDRE, & S. DEMERS. 1986. Photosynthetic and pigment responses of sea-ice microalgae to changes in light intensity and quality. **J. Exp. Mar. Biol. Ecol.** 101:211-236.

RUNGE, J.A. & R.G. INGRAM. 1988. Underice grazing by planktonic, calanoid copepods in relation to a bloom of ice microalgae in southeastern Hudson Bay. **Limnol. Oceanogr.** 33:280-286.

SIFERD, T., M.A. BERGMANN, & H.E. WELCH. Distribution of sympagic amphipods near Chesterfield Inlet, northwest Hudson Bay. (In prep.)

SUTCLIFFE, W.H. JR., R.H. LOUCKS, K.F. DRINKWATER, & A.R. COOTE. 1983. Nutrient flux onto the Labrador Shelf from Hudson Strait and its biological consequences. **Can. J. Fish. Aquat. Sci.** 40:1692-1701.

WELCH, H.E. & M.A. BERGMANN. 1989. Seasonal development of ice algae and its prediction from environmental factors near Resolute, N.W.T., Canada. **Can. J. Fish. Aquat. Sci.** 46:1763-1804.

WELCH, H.E., M.A. BERGMANN, T. SIFERD, & P.S. AMARUALIK. Seasonal development of ice algae in northwestern Hudson Bay, near Chesterfield Inlet NWT. (In prep.)

ZOOPLANKTON AND ICE FAUNA

E.H. Grainger

Department of Fisheries and Oceans
Arctic Biological Station
555 boul. St-Pierre
Ste-Anne-de-Bellevue, Québec, H9X 3R4

ZOOPLANKTON

Although it is relatively close and accessible from the south, Hudson Strait is still less understood biologically than several more remote parts of the Canadian Arctic. Since Sidney SMITH reported the planktonic mysid *Mysis oculata* from Port Burwell (Killinek) in 1885, fewer than 20 papers, most of them concerned with the eastern end of the Strait, have been published on the zooplankton of Hudson Strait. There has been some research on the biology of a few of the zooplankters, such as the chaetognath *Sagitta elegans* (DUNBAR 1941, 1962) and the amphipod *Themisto libellula* (DUNBAR 1957). Most of the literature, however, deals only with distribution (DUNBAR 1942a, 1942b, 1954; FONTAINE 1955; GRAINGER 1954, 1961, 1963; KERSWILL 1940; SQUIRES 1957, 1965, 1966). The most recent publication on the zooplankton of the Strait appeared more than 20 years ago. There has been more recent work done in Hudson Strait, but it is not yet published. During the last 2 or 3 years, research cruises carried out in Hudson Strait primarily to collect physical oceanographic data and to examine prospects for the commercial exploitation of fishes and invertebrates have yielded zooplankton data. Reports on some of this material are included in other parts of this volume.

While there is a dearth of information about the ecology of the zooplankton of Hudson Strait, there is considerably more known from the adjoining waters of Hudson Bay, Foxe Basin and Frobisher Bay. Much of what is discussed below does not come from Hudson Strait in its narrowest geographical sense, but from a somewhat broader marine area of which the Strait forms a part.

From our knowledge of neighbouring waters, we can expect to find around 150 species of zooplankton in Hudson Strait, excluding Protista and meroplankton. There is a marked homogeneity in the composition of zooplankton throughout most of the waters of the Canadian Arctic, the major qualitative differences marking areas of mixing of Arctic and Atlantic (or Pacific) waters. Hudson Strait is subarctic, following DUNBAR's (1951) definition; it is a region of mixed waters, of Arctic and North Atlantic origin. A North Atlantic copepod, *Calanus finmarchicus*, serves as an indicator of mixed water through the length of Hudson Strait (GRAINGER 1963), showing relatively strong presence at the eastern end of the Strait and a gradually weakening one towards the west, and reaching westward only as far as the northeast corner of Hudson Bay and southern Foxe Channel.

In the easternmost part of the Strait, deep intruding Atlantic water is present below 100 m (DUNBAR 1958). This water transports into the eastern end of the Strait a number of Atlantic zooplankton indicator species, including certain copepods of the genera *Aetideopsis*, *Chiridius*, *Gaidius*, *Heterorhabdus*, *Pleuromamma* and *Xanthocalanus* (FONTAINE 1955; unpublished data Arctic Biological

Station), and the decapods *Sergestes* and *Pasiphaea* (SQUIRES 1957). These relatively warm-water species tend to occur at a depth below that of the so-called arctic species, which are typical (in summer) of near-surface waters of the Arctic Ocean and circumpolar seas. Study of the interactions of these species groups may help us to understand the dynamics of the waters in which they occur. This is especially important in eastern Hudson Strait where there is a requirement to identify the factors controlling the distribution and abundance of the Atlantic-associated, potentially economically interesting species such as shrimp and Atlantic cod.

Zooplankton seasonal cycles have not been demonstrated in Hudson Strait. They may be expected, however, to resemble closely what has been shown in the adjoining waters of Frobisher Bay (GRAINGER 1975). There, the biomass rapidly increases to 20-30 times the lowest winter levels during June-July, peaks in July-August, then declines more gradually than it grew, to reach its minimal levels in April-May. Annual cycles of zooplankton and phytoplankton display close seasonal agreement, indicating a strong dependance by the animals on available plant food. Mean phytoplankton values from mid-July to mid-August were a little less than 8 g C m^{-2}, mean zooplankton about 0.7 g C m^{-2} in a year when the estimated total primary production was calculated to be 70-100 g C m^{-2}. Levels of this order may be expected in parts of Hudson Strait. At the ends of the Strait, especially the eastern end, primary production is probably greater.

Biochemical and energy contents of zooplankton have been studied in waters bordering the Strait. Caloric content of various species groups shows copepods (mainly the larger calanoids) with the highest relative energy values, followed fairly closely by euphausiids (PERCY & FIFE 1985). Lowest were the coelenterates and ctenophores. The ctenophore *Mertensia ovum* dominated the macrozooplankton in Frobisher Bay and accounted for more than half the total macrozooplankton calories. This is of particular interest because the relative caloric content of ctenophores was low, hence they achieved dominant status solely on account of their very large biomass. Preliminary study suggests they may not dominate the macrozooplankton in Hudson Strait, in parts of which at least the larger crustaceans may take their place.

Data from Frobisher Bay show that many of the herbivorous zooplankters feed on a wide range of phytoplankton species, of which *Chlamydomonas* and *Chaetoceros* are among the most important. The food of carnivorous zooplankton consists mainly of the abundant copepods *Pseudocalanus* and *Calanus* and the seasonally plentiful planktonic larvae of the barnacle *Balanus*.

A study carried out in Digges Sound, at the western end of Hudson Strait, showed the central position occupied by zooplankton in the food web relating to the thick-billed murre (GASTON *et al.* 1985). In addition to forming a major food source for the murre, zooplankton was shown to be a major source of nourishment for a number of fishes, including the arctic cod and arctic charr, for other birds and for marine mammals.

Major trophic links are gradually becoming clearer in northern waters. The barest start has been made in Hudson Strait, where the study of trophic relationships will form a large and important part of future work.

ICE FAUNA

During winter a special animal community, related in part to the plankton associated with the sea bottom (the hyperbenthos) and partly to the deeper benthic fauna, develops within the lower few centimetres of annual sea ice throughout the Arctic. The community is often dominated numerically by nematodes, polychaete larvae and cyclopoid and harpacticoid copepods (CAREY 1985).

Concentrations of animals in the ice may be extremely high. In waters close to Hudson Strait, animals in the ice ($>10^6$ m^{-3}) have been found to be some 4 orders of magnitude more concentrated than those in the water below the ice between February and May, and about 3 orders greater than the density of zooplankton found at the height of the summer season (GRAINGER & HSIAO, 1990).

Concentrated and readily available food thus develops in the lower levels of the ice, where available nutrients and light promote growth of a rich flora which is fed upon *in situ* by the ice meiofauna. Major ice meiofaunal food genera include *Chlamydomonas*, *Nitzschia* and *Navicula*. This relatively abundant ice food source is present at a time when the supply of algal food available to animal herbivores living in the water column below the ice is low. The presence of ice permits the development in late winter and early spring of a relatively rich food source for animal predators which would not be available in the absence of sea ice.

Trophic links between the sea ice and the water column under the ice have been demonstrated in areas close to Hudson Strait. *Tisbe furcata*, a harpacticoid copepod apparently nourished in winter mainly by the ice algae (GRAINGER & HSIAO 1990), and *Pseudocalanus* sp., a calanoid copepod supported under the ice at least partly by organisms associated with the ice water interface (RUNGE & INGRAM 1988; GRAINGER & HSIAO 1990), are both fed upon by the pelagic amphipod *Gammarus* sp. at the bottom surface of the ice and in the water below (GRAINGER & HSIAO 1990). Another common amphipod under the ice, *Onisimus*, feeds on ice diatoms when young and on additional under-ice flora when larger. It is eaten in turn by *Gammarus setosus* (GRAINGER & HSIAO 1990). Both *Gammarus* and *Onisimus* are fed on by the arctic cod, *Boreogadus saida* (BRADSTREET & CROSS 1982). The amphipods and *Boreogadus* are important components in the diets of *Uria lomvia*, the thick-billed murre (BRADSTREET & CROSS 1988) and Phoca hispida, the ringed seal (McLAREN 1958).

Although there is as yet no specific information available about the ice biota of Hudson Strait, it is likely that the sea ice, as shown in waters close by, will be found to support a far-reaching food chain. The sea ice and its biota should form, therefore, an important part of the future research in Hudson Strait.

REFERENCES

BRADSTREET, M.S. & W.E. CROSS. 1982. Trophic relationships at high arctic ice edges. **Arctic** 35:1-12.

CAREY, A.C. 1985. Marine ice fauna: arctic. pp. 173–190. *In*: Horner, R.A.(ed). **Sea ice biota**. CRC Press, Boca Raton, Florida.

DUNBAR, M.J. 1941. The breeding cycle in *Sagitta elegans elegans* Aurivillius. **Can J. Res**. D 19:258–266.

DUNBAR, M.J. 1942a. Marine macroplankton from the Canadian eastern Arctic. I. Amphipoda and Schizopoda. **Can. J. Res**. D 20:33–46.

DUNBAR, M.J. 1942b. Marine macroplankton from the Canadian eastern Arctic. II. Medusae, Siphonophora, Ctenophora, Pteropoda and Chaetognatha. **Can. J. Res**. D 20:71–77.

DUNBAR, M.J. 1951. Eastern arctic waters. **Bull. Fish. Res. Board Can.** 88. 131 pp.

DUNBAR, M.J. 1954. The Amphipod Crustacea of Ungava Bay, Canadian eastern Arctic. **J. Fish. Res. Board Can.** 11:709–798.

DUNBAR, M.J. 1957. The determinants of production in northern seas: a study of the biology of *Themisto libellula* Mandt. **Can. J. Zool**. 35:797–819.

DUNBAR, M.J. 1958. Physical oceanographic results of the "Calanus" expeditions in Ungava Bay, Frobisher Bay, Cumberland Sound, Hudson Strait and northern Hudson Bay, 1949–1955. **J. Fish. Res. Board Can.** 15:155–201.

DUNBAR, M.J. 1962. The life cycle of *Sagitta elegans* in arctic and subarctic seas, and the modifying effects of hydrographic differences in the environment. **J. Mar. Res**. 20:76–91.

FONTAINE, M. 1955. The planktonic copepods (Calanoida, Cyclopoida, Monstrilloida) of Ungava Bay, with special reference to the biology of *Pseudocalanus minutus* and *Calanus finmarchicus*. **J. Fish. Res. Board Can.** 12:858–898.

GASTON, A.J., D.K. CAIRNS, R.D. ELLIOT & D.G. NOBLE. 1985. A natural history of Digges Sound. **Can. Wildlife Serv. Rep. Ser.** 46. 63 pp.

GRAINGER, E.H. 1954. Polychaetous annelids of Ungava Bay, Hudson Strait, Frobisher Bay and Cumberland Sound. **J. Fish. Res. Board Can.** 11:507–528.

GRAINGER, E.H. 1961. The copepods *Calanus glacialis* Jaschnov and *Calanus finmarchicus* (Gunnerus) in Canadian arctic-subarctic waters. **J. Fish. Res. Board Can.** 18:663–678.

GRAINGER, E.H. 1963. Copepods of the genus *Calanus* as indicators of eastern Canadian waters. **Roy. Soc. Can. Spec. Publ.** 5:68–94.

GRAINGER, E.H. 1975. A marine ecology study in Frobisher Bay, arctic Canada. Pp. 261–266. *In*: Cameron T.W.M. & L.W. Billingsley (eds). **Energy flow - its biological dimensions**. Royal Soc. Can., Ottawa.

GRAINGER, E.H. & S.I.C. HSIAO. 1990. Trophic relationships of the sea ice meiofauna in Frobisher Bay, arctic Canada. **Polar Biol**. 10:283–292.

KERSWILL, C.J. 1940. The distribution of pteropods in the waters of eastern Canada and Newfoundland. **J. Fish. Res. Board Can.** 5:23–31.

McLAREN, I.A. 1958. The biology of the ringed seal (*Phoca hispida* Schreber) in the eastern Canadian Arctic. **Bull. Fish. Res. Board Can.** 118. 97 pp.

PERCY, J.A. & F.J. FIFE. 1985. Energy distribution in an arctic coastal macrozooplankton community. **Arctic** 38:39–42.

RUNGE, J.A. & R.G. INGRAM. 1988. Underice grazing by planktonic, calanoid copepods in relation to a bloom of ice microalgae in southeastern Hudson Bay. **Limnol. Oceanogr**. 33:280–286.

SMITH, S.J. 1885. List of Crustacea from Port Burwell. p. 57–58. *In*: Bell, R. (ed). Observations on the geology, mineralogy, zoology and botany of the

Labrador coast, Hudson's Strait and Bay. **Rep. Prog. Geol. Surv. Can.** 1882-83-84 DD.
SQUIRES, H.J. 1957. Decapod Crustacea of the Calanus expeditions in Ungava Bay, 1947 to 1950. **Can. J. Zool.** 36:463-494.
SQUIRES, H.J. 1965. Larvae and megalopa of *Argis dentata* (Crustacea: Decapoda) from Ungava Bay. **J. Fish. Res. Board Can.** 22:69-82.
SQUIRES, H.J. 1966. Distribution of decapod Crustacea in the northwest Atlantic. **Serial Atlas of the Marine Environment**. Amer. Geogr. Soc. 12. 4 pp. + 4 pl.

MACROINVERTEBRATE ASSEMBLAGES

C. Hudon

Arctic Biological Station
Department of Fisheries and Oceans
555 boul. St-Pierre
Ste-Anne-de-Bellevue, Québec, H9X 3R4

INTRODUCTION

A review of the literature reveals that studies of the benthos in Hudson Strait consist of either qualitative faunistic inventories or exploratory surveys focussing on potentially exploitable resources. Understandably, the pictures of the benthic assemblages resulting from these two types of studies are very different, although they should be seen as complementary rather than contradictory. Faunistic inventory concentrated on identification, and generated impressive species lists based on qualitative sampling with a variety of gear types. Such information is useful for examining species diversity and biogeographic affinities (Table 3) in the benthic communities and for identifying frequently encountered species, regardless of their biomass. In contrast, exploratory surveys for exploitable resources focused on the capture of single species, using commercial-sized gear over a narrow range of depths and bottom types. As a result, the size structure of the target species is biased towards larger individuals, and species captured incidentally are usually not properly identified or recorded. Additional valuable information could be obtained from more quantitative faunistic sampling and by putting more emphasis on by-catch collection during exploratory surveys.

This review examines three communities characteristic of Hudson Strait waters, and attempts to draw an association between community organisation and the ecology of individual species. The invertebrate communities were divided into nearshore, coastal and offshore areas. When data allowed, species distribution was mapped and related to critical physical factors. I have also reviewed the available biological and ecological information about those species offering some potential for human consumption. I include proposals for research programs addressing poorly known aspects of their biology as well as for specific, management related problems in each area.

NEARSHORE COMMUNITY

The species assemblage commonly found in intertidal and shallow subtidal areas is not highly diversified (See WACASEY & ATKINSON 1987 and ATKINSON & WACASEY 1989 for complete species lists). Eight species are commonly found. Of these, the blue mussel (*Mytilus edulis*) is the most abundant. Although gammarid amphipods represent the most diverse taxon (19 species), only *Gammarus oceanicus* and *G. setosus* are commonly encountered. Other common species are a littorinid gastropod, two barnacle species, and three bivalves. Interestingly, this assemblage is a simplified version of the boreal subarctic assemblage found in the St. Lawrence Estuary and Gulf, where harsh environmental conditions are also encountered during winter.

Table 3. Biogeographic affinities of Hudson Strait benthic invertebrates.

Taxon	% of Total Species				Number of Species	Reference
	Circum-polar	Arctic	Sub-arctic	Boreal		
Polychaeta	57	20	66		74	GRAINGER 1954
Cirripedia	100	100	100	100	3	BOUSFIELD 1955
Amphipoda	40	74	100	50	114	DUNBAR 1954
Decapoda	35	65	100	82	17	SQUIRES 1957
Echinodermata	58	77	85	46	26	GRAINGER 1955

A review of the bivalves of the Canadian Arctic is available (LUBINSKY 1980). Several species of shallow-water bivalves (*Mytilus edulis, Macoma balthica, Mya* spp.), occur from Killinik to James Bay. The blue mussel (Fig. 13a) predominates in the intertidal zone of rocky shores, while the latter two are more commonly found on soft bottoms in the subtidal zone. In Hudson Strait, large mussel beds are present in the vicinity of Kangirsujuaq (Wakeham Bay) and Salluit, possibly because of the protection against ice scouring that the fjords offer. In Wakeham Bay, the beds can be harvested in winter, as they can be reached through holes in the fast ice at low tide.

A study of blue mussel biology and comparisons of their growth rates at several northern locations (LUBINSKY 1958) found extremely low growth rates (Fig. 13b). Specimens collected in 1989 in Quaqtaq support this observation (HUDON, unpubl. data), as mussels reached a size of only 5 cm at about 8 years of age. This size is reached after 2 years in the southern Gulf of St. Lawrence. In addition, annual recruitment appears uncertain, since no individuals < 4 years were collected on the Quaqtaq bed. Ice scouring over the most exposed areas of the shoreline appeared to be a major factor in determining blue mussel's shape, as well as its limited abundance and distribution (LUBINSKY 1958). In southern Hudson Bay where the surface salinities are less than 23 ppt. and mixing of water is poor, *Mytilus* remains small, despite higher temperatures. Larger shells are found at the mouth of Hudson bay where salinity reaches 32 ppt. and there is an influx of cold water from Foxe Channel and Hudson Strait (LUBINSKY 1958).

Little is known about the biology and ecology of other species of the nearshore communities of Hudson Strait, or about the effects of physical and biological factors on their structure. As with the blue mussel, a large body of literature is available for similar communities in more southerly latitudes (e.g. St. Lawrence Estuary and Gulf), which could provide a basis for interesting comparative studies.

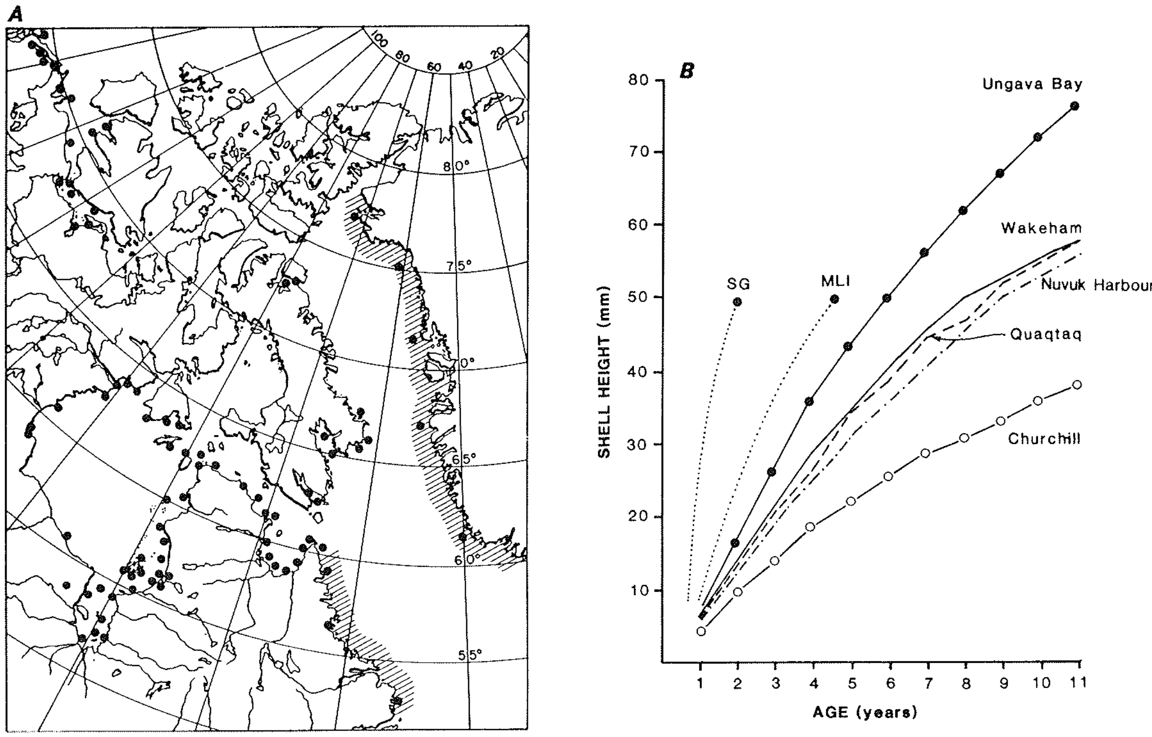

Figure 13. A) The distribution of the blue mussel *(Mytilus edulis)* in the coastal waters of Hudson Bay and Hudson Strait (from LUBINSKY 1980).

B) Growth of Mytilis edulis in Ungava Bay, Wakeham Bay, Hudson Bay (from LUBINSKY 1980) and the Gulf of St. Lawrence (SG = southern Gulf, MLI = Maurice Lamontagne Institute, Mont Joli).

Recommended studies include:

1) An evaluation of the yearly production and energy budget of an intertidal mussel bed community, including the role of other dominant species (barnacles, gammarid amphipods, etc.).

2) A seasonal study of the blue mussel gonad development, larval production and spat deposition, to determine the influence of physical (ice, temperature, circulation) and biological (phytoplankton bloom) conditions.

3) The evaluation of the age structure of several populations of blue mussel and other molluscs, to determine if there are environmental constraints to recruitment, operating on a large geographical scale.

COASTAL COMMUNITY

The coastal community is probably the best known (if only in qualitative terms), because sampling has taken place since the 1940's (DUNBAR 1956). A review of the biogeographic affinities of the species (Table 3) reveals that most of the

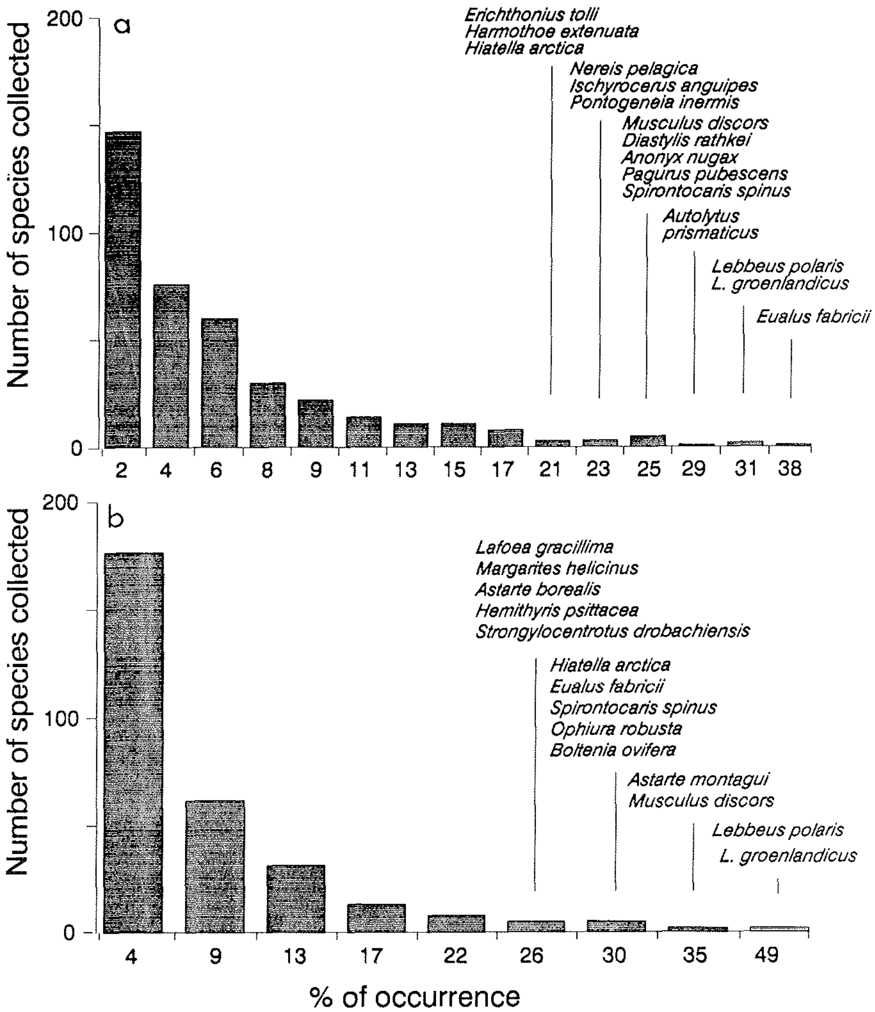

Figure 14. Frequency of collection of benthic invertebrates from soft-bottom, coastal areas of A) Ungava Bay, 1947-1951 and B) Hudson Strait, 1947-1970.

coastal species collected in Ungava Bay have a broad distribution range. Hudson Strait appears to be an area in which influences of arctic, subarctic and boreal environments overlap (LUBINSKY 1980). This mixed influence is also apparent in the demersal fish assemblages (HUDON 1990).

A qualitative survey of invertebrate species in Ungava Bay and Hudson Strait, using various gear types over a wide range of depths (2-274 m), yielded 411 and 541 species, respectively (See WACASEY & ATKINSON 1987 and ATKINSON & WACASEY 1989 for complete species lists). Fewer than 15 species (2% of the total) occurred in 10 % or more of the samples (Fig. 14). The results over-emphasize the fauna of sandy-muddy bottom as well as pelagic species, consisting of suprabenthic (Caridean shrimps: *Eualus fabricii*, *Lebbeus* spp., *Spirontocaris spinus*, *Argis dentata*; Amphipods: *Anonyx nugax*, *Ischyrocerus anguipes*, *Pontogeneia inermis*) and epi-endobenthic (Cumacean: *Diastylis rathkei*, Crabs: *Pagurus pubescens*, *Hyas coarctatus*) decapods (Fig. 14). This selectivity results from the use of nets and dredges which collect mainly pelagic, suprabenthic and soft bottom invertebrates. Quantitative sampling in other eastern arctic localities (e.g. Frobisher Bay) has shown polychaetes and amphipods to be the most diverse groups, each with over 100 species (WACASEY & ATKINSON 1987).

A considerably different picture of the composition of the benthos is obtained from the by-catch of scallop dredging, which collects only species of relatively large size and high numbers. During a survey for Iceland scallop in Hudson Strait, tows were made at 30–100 m depths, for a standard duration of 5 min. The most abundant species of invertebrates associated with the Iceland scallop were the spider crab (*Hyas coarctatus*, up to 8 kg tow^{-1}) and several species of seastars, ascidians and sea cucumbers (*Cucumaria frondosa*, *Psolus fabricii*, up to 260 kg tow^{-1}).

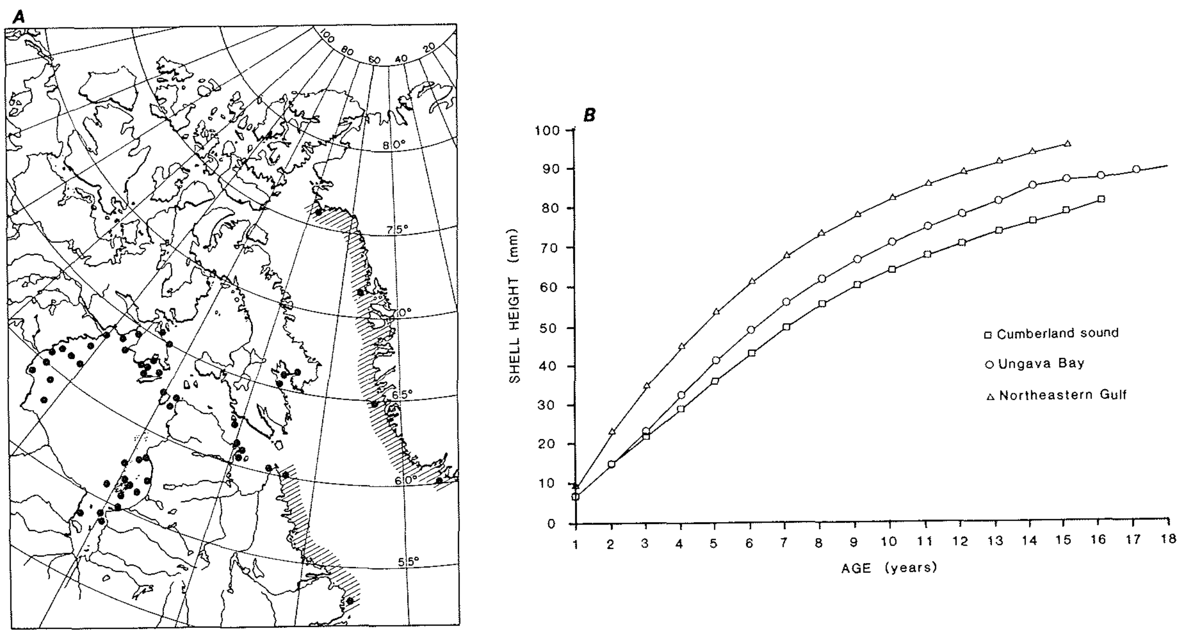

Figure 15. A) Distribution of Iceland scallop (*Chlamys islandica*) in the coastal waters of Hudson Bay and Hudson Strait (from LUBINSKY 1980)
B) Growth of *Chlamys islandica* in Cumberland Sound, Ungava Bay and Gulf of St. Lawrence (from CRAWFORD, 1988)

Distribution maps (Fig. 15a) report the occurrence of the Iceland scallop in Hudson Bay, off Belcher Islands, and in northern James Bay (LUBINSKY 1980), where average bottom salinities of 24 ppt. are near the limit of tolerance for that species. Exploratory fishing for Icelandic scallops (*Chlamys islandica*) has been carried out off Killiniq Island (GILLIS & ALLARD 1986; GILLIS *et al.* 1987), southern Baffin and Akpatok Islands and Quaqtaq (GILLIS & ALLARD 1988), Frobisher Bay (CRAWFORD, unpubl. data), western Ungava Bay and western Baffin Island (ALLARD & GILLIS 1989), the southern coast of Hudson Strait (ALBRIGHT 1989) and in Cumberland Sound. Concentrations of scallops worthy of further exploration were located in Ungava Bay (Akpatok and Killiniq Islands), near Quaqtaq and Wakeham Bay. In northern waters, a fishery for the icelandic scallop has operated out of Nain, Labrador since the late 1970's (BARNEY *et al.* 1982), and more recently in Cumberland Sound (MACKAY 1986; CRAWFORD 1988, 1989). Growth in all these areas is slower than that of scallops in the Gulf of St.Lawrence. A size of 5 cm is attained after 4 years in the Gulf of St.Lawrence, but only after 7 to 9 years in northern populations (ALLARD & GILLIS 1989) (Fig. 15b). Northern populations also appear to reach a smaller asymptotic size than those in the Gulf of St.Lawrence.

The oceanographic factors determining the location and size of Iceland scallop beds are not clearly known. Off Lofoten Islands (Norway), the densest populations of *Chlamys islandica* are found in fjords with a sill, in places with comparatively strong current (WIBORG 1963). Akpatok bank (TAGGART *et al.* 1989), Killiniq Island and Diana Bay (CANADIAN HYDROGRAPHIC SERVICE 1987) are all areas of intense water mixing. The occurrence of scallop beds in frontal areas was reported for *Placopecten magellanicus* in the southern Gulf of St.Lawrence and the Atlantic coast. Their occurrence in these areas might be related to higher phytoplankton production and/or mechanisms for larval retention (SINCLAIR *et al.* 1985). Further exploration for scallop in western Hudson Strait and northeastern Hudson Bay should include the collection of physical oceanographic data and focus on areas of intense water mixing. Given the known distribution of the scallop (LUBINSKY 1980), it is possible that concentrations could be found off Salisbury, Mansel, Long and the Belcher islands; all are areas of intense water mixing.

Additional information is required about the distribution and biology of Icelandic scallop in Canadian Arctic waters. However, the biology and metabolism of Iceland scallop are known from studies in the Gulf of St.Lawrence and Scandinavian waters. This information has led to several questions about its ecology and life cycle:

1) The identification of areas of concentration and characterization of their physical regime.

2) The linkage between phytoplankton abundance and adult growth, gonad maturation and larval release.

3) Larval transport, population mixing and stock identification.

4) The effect of surface sediment enrichment (through production of fecal matter) on the benthic community.

5) The study of the population dynamics of a virgin Icelandic scallop stock, and of its response to various levels of exploitation.

OFFSHORE COMMUNITY

The only information about the demersal invertebrate assemblages comes from the by-catch of shrimp (*Pandalus* spp.) exploratory surveys using trawls (Fig. 16, Table 4, data sources cited in HUDON 1990). This list is still very incomplete,

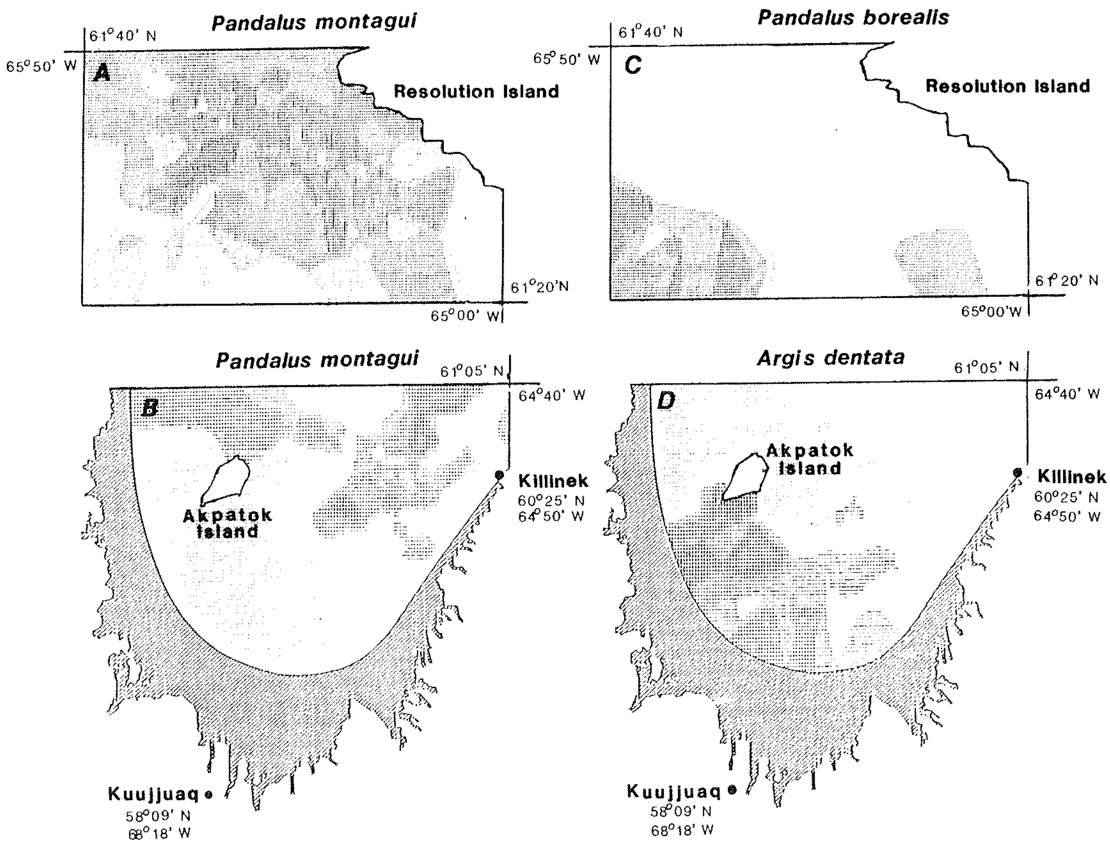

Figure 16. Distribution of biomass of *Pandalus montagui* (A, B), *P. borealis* (C) and *Argis dentata* (D) in eastern Hudson Strait and Ungava Bay (from HUDON 1990). Each shade of grey represents an abundance class expressed as the Naperian logarithm (ln (X + 1) of the total weight (Kg) caught during a standard 0.5 hr tow.

since shrimp trawls only collect relatively large suprabenthic invertebrates. Ungava Bay has the most diversified decapod fauna (20 groups), more than twice the number captured in other areas of Hudson Strait. Ungava Bay has a predominance of arctic decapod species such as *Lebbeus* spp., *Argis dentata*, and *Sclerocrangon* sp.

A change of dominance is observed across the eastern end of Hudson Strait: *Pandalus borealis* predominates in the Labrador Sea while *P. montagui* is common in eastern Hudson Strait. This transition can be related to the temperature tolerance of these species. *Pandalus montagui* tolerates a wider range of temperature (-1 to 20°C) (ALLEN 1963; SQUIRES 1968) than *P. borealis* (0 to 11°C) (SIMPSON *et al.* 1970; FONTAINE 1970). Of all the pandalids in the northwest Atlantic, *P. montagui* is the only one which inhabits colder arctic waters <1.5°C as far north as Ungava Bay (SQUIRES 1957, 1966). The change of dominance from *P. borealis* to *P. montagui* in the Hudson Strait-Ungava Bay area may be attributed to the greater influence of arctic waters there. A small population of *P. borealis*, either indigenous or carried by water movements, occurs in the deep portion of the Strait where Labrador Sea water penetrates.

In eastern Hudson Strait, major areas of concentration of *P. montagui* are located west of Resolution Island, and in the northeast part of Ungava Bay (Fig. 16a). Catch rates for pandalid shrimp are consistently higher off Resolution Island (1271 kg 0.5 hr tow^{-1}) than off northeastern Ungava Bay (364 kg 0.5 hr tow^{-1}). The brown shrimp, *Argis dentata*, is abundant in southwestern Ungava Bay (Fig. 16d), where arctic waters are influenced by freshwater inputs. It has been reported mostly in waters < 0°C between 50 and 200 m (SQUIRES 1966). This species yielded the second largest catch in Ungava Bay, with a total weight of 208.6 kg (ALLARD 1980).

Pandalid shrimps occur sporadically as far west as the 72° meridian (western tip of Ungava Bay). Recent surveys in the western part of the Strait as far as Foxe Basin and northern Hudson Bay (ALLARD 1990) failed to discover significant concentrations of any commercially exploitable species. Western Hudson Strait is characterized by low abundances of other arctic shrimp species (mostly *Argis dentata, Sclerocrangon* spp. and *Lebbeus* spp.).

The diel cycle of the vertical distribution of *Pandalus montagui* near Resolution Island in relation to their sex, size and maturity stage was investigated (HUDON *et al.* in prep.). An extensive upward migration was observed at night, followed by a downward migration at dawn. Vertical movement was considerable and significant numbers of animals were taken in the upper 50 m in water depths of 275-350 m. Contrary to previous findings for *P. borealis*, there was no vertical segregation by sex, size or maturity stage. Simultaneous acoustic sampling showed that rapid changes in the vertical distribution of the shrimps, as determined by BIONESS sampling, were concurrent with the appearance of transient, highly dynamic, discrete, dense layers (CRAWFORD *et al.* in prep.). These results suggest that the vertical movement of *P. montagui* might be enhanced by intense mixing of waters in eastern Hudson Strait. The pattern observed could result from an interaction between active diel migratory behaviour and passive entrainment by turbulence.

The stomach contents of shrimp during their vertical migrations in the water column were identified and compared with the available prey captured simultaneously in each depth layer (HUDON *et al.* in prep.). No obvious patterns related to sex, size, depth and time of sampling were found. Shrimp fed on a variety of planktonic organisms, mostly copepods, chaetognaths, hyperid amphipods, cephalopods and pteropods. Chaetognaths and pteropods occurred more frequently in the shrimp stomachs than in the plankton samples, whereas other prey were found in direct relation to their abundance. Benthic prey, such as ascidians, mysids, polychaetes and cumaceans were also found in small numbers in the stomach contents. The stomachs of shrimp from a bottom trawl in the same

Table 4. Benthic invertebrate species collected in deep (>300m) offshore waters of eastern Hudson Strait using shrimp trawls (HUDON 1990).

PHYLUM	CLASS	GENUS	SPECIES
Porifera		Unidentified	
Coelenterata	Hydrozoa	Unidentified	
		Unidentified	
	Anthozoa	*Actinauges*	sp.
		Bolocera	sp.
Mollusca	Gastropoda	*Buccinum*	*undatum*
		Colus	*stimpsoni*
		Neptunea	sp.
		Unidentified	
	Pelecypoda	*Clinocardium*	*ciliatum*
		Chlamys	*islandica*
		Macoma	sp.
		Yoldia	*myalis*
	Cephalopoda	*Bathypolypus*	*arcticus*
		Gonatus	sp.
		Octopus	sp.
		Sepiola	sp.
Annelida	Polychaeta	*Amphrodita*	sp.
Arthropoda	Pycnogonida	*Nymphon*	sp.
	Crustacea	*Balanus*	sp.
		Argis	*dentata*
		Eualus	*fabricii*
		Eualus	*gaimardi*
		Hyas	*coarctatus*
		Lebbeus	*groenlandicus*
		Lebbeus	*polaris*
		Lithodes	sp.
		Munidopsis	*curvirostra*
		Pagurus	sp.
		Pandalus	*borealis*
		Pandalus	*montagui*
		Pasiphaea	*multidentata*
		Pasiphaea	*tarda*
		Sabinea	sp.
		Sclerocrangon	*boreas*
		Sclerocrangon	*ferox*
		Spirontocaris	*phipps*
		Spirontocaris	*spinus*

Table 4. *Continued.*

Phylum	Class	Genus	Species
Ectoprocta		Unidentified	
Brachiopoda		Unidentified	
Echinodermata	Asteroidea	*Solaster*	*papposus*
		Ctenodiscus	*crispatus*
		Henricia	sp.
		Hippasteria	*phrygiana*
		Leptasterias	sp.
		Poraniomorpha	*hispida*
		Pteraster	sp.
		Solaster	*endeca*
	Ophiuroidea	*Gorgonocephalus*	*arcticus*
		Ophiopholis	*aculeata*
		Ophiura	*sarsi*
		Psilaster	*andromeda*
	Echinoidea	*Strongylocentrotus*	*droebachiensis*
	Holothuroidea	*Cucumaria*	*frondosa*
	Crinoidea	Unidentified	
Chordata	Ascidiacea	*Boltenia*	*ovifera*

area contained chitinous debris, sand grains and small amounts of benthic organisms. These results suggest that considerable feeding takes place in the plankton, during vertical migration. This component of the diet is not adequately represented in shrimps sampled near the bottom.

Year-to-year variability in shrimp catches off Resolution Island and in northeastern Ungava Bay is high (DFO 1990). Important catches were recorded in 1981 and 1988-89, which also corresponded to periods of high shrimp catches in Davis Strait, the Labrador Sea and the Gulf of St.Lawrence. This suggests the influence of an environmental factor over a large geographical area. The influence of yearly variations in ice distribution on abundance is currently being investigated.

Although the distribution of pandalid shrimp in Hudson Strait is known, the general state of knowledge of the biology, ecology and stock identity of *P. montagui* is poor. Future research should include studies of:

1) The life history and growth of *P. montagui*, because current models utilize the values previously developed for *P. borealis*.

2) The influence of movements of water mass on the advection of adults and larvae. This will help determine if populations in the two areas of abundance are part of a single stock, or if they should be managed separately.

3) The other members of the demersal community should be sampled, using a method other than shrimp trawl.

4) The predators of shrimp and their effects on population density should be studied (turbot, cod, beluga). In the case of the beluga, there are concerns about the potential effect of shrimp harvest depleting the whales' food supply.

5) The population should be assessed and year-to-year variations of the commercial catches should be monitored, since there are indications that this area is subject to large-scale, long-term climatic or hydrographic fluctuations.

REFERENCES

ALBRIGHT, D. 1989. Report on the exploratory fishing for the Iceland scallop (*Chlamys islandica*) and the Greenland halibut (*Rheinhardtius hippoglossoides*) along the coast of Hudson Strait, between Quaqtaq and Salluit, August 1989. Unpublished manuscript report available from the Dept. of Fisheries and Oceans, Arctic Biological Station, 555 boul. St-Pierre, Ste-Anne-de-Bellevue, Qué. H9X 3R4.

ALLARD, M. et D. GILLIS. 1989. Angusalluq survey, Ungava Bay/Hudson Strait. Unpublished report, **Makivik Corp. Research Dept.** Available from Makivik Corp.,650, 32nd Ave., 6th floor, Lachine, P.Q. H8T 1Y4.

ALLARD, M.R. 1980. Ungava Bay exploratory cruise: September 1979. Unpublished report, **Makivik Corp. Research Dept.** 23 pp. + 4 App. Available from Makivik Corp., 650, 32nd ave., 6th floor, Lachine, P.Q. H8T 1Y4.

ALLARD, M.R. 1990. Exploratory cruise in central and western Hudson Strait, northern Hudson Bay and Foxe Channel: August-September 1989. Unpublished report, **Makivik Corp. Research Dept.** Available from Makivik Corp., 650, 32nd ave., 6th floor, Lachine, P.Q. H8T 1Y4.

ALLEN, J.A. 1963. Observations on the biology of *Pandalus montagui* [Crustacea: Decapoda]. **J. Mar. Biol. Assoc. U.K.** 43: 665-682.

ATKINSON, E.G. & J.W. WACASEY. 1989. Benthic invertebrates collected from Hudson Strait, Foxe Channel and Foxe Basin, Canada, 1949 to 1970. **Can. Data Rep. Fish. Aquat. Sci.** 746. 98 pp.

BARNEY, W., C. CHAFFEY & C. COLLIER. 1982. Exploratory scallop survey, Labrador, 1982. (Nain area). Unpublished report, **Fisheries and Oceans Canada**, Fisheries Development Branch, St.John's, Nfld.

BOUSFIELD, E.L. 1955. The cirripede crustacea of the Hudson Strait region, Canadian eastern Arctic. **J. Fish. Res. Board Can.** 12:762-767.

CANADIAN HYDROGRAPHIC SERVICE. 1987. **Canadian Tide and Current Tables. Vol. 4. Arctic and Hudson Bay.** DFO, Canadian Hydrographic Serv. 72 pp.

CRAWFORD, R., C. HUDON & D. PARSONS. 1990. A study of the vertical distribution of the shrimp (*Pandalus montagui*) using hydroacoustics and multistage plankton sampling. Unpublished report. Abstract presented to ICES Conference Moncton, June 1990.

CRAWFORD, R. 1988. Iceland scallops in the eastern Arctic. **AFSAC Background document** 88/89-07. 17 pp. Available from DFO, Central and Arctic region, Winnipeg, Manitoba R3T 2N6.

ORAWFORD, R. 1989. Exploitation of Arctic fishes. **Can. Man. Rep. Fish. Aquat. Sci.** 2002. 43 pp.

DFO. 1990. **Shrimp landing statistics for the year 1989.** Available from Department of Fisheries and Oceans, Statistics Branch, Quebec. G1K 7Y7.

DUNBAR, M.J. 1954. The amphipod crustacea of Ungava Bay, Canadian eastern Arctic. **J. Fish. Res. Board Can.** 11:709-798.

DUNBAR, M.J. 1956. The *Calanus* expeditions in the Canadian Arctic, 1947 to 1955. **Arctic** 9:178-190.

FONTAINE, B. 1970. La crevette profonde (*Pandalus borealis*) dans la région de Nord-Ouest Atlantique. **Sciences et Pêches** 197. 14 pp.

GILLIS, D.J., & M.R. ALLARD. 1986. Killiniq Fisheries Project. Phase II. Unpublished report. **Makivik Corp. Research Dept.** Available from Makivik Corp., 650, 32nd ave., 6th floor, Lachine, P.Q. H8T 1Y4.

GILLIS, D.J., & M.R. ALLARD. 1988. The "Anne S. Pierce" survey. A report on exploratory fishing for Icelandic Scallop (*Chlamys islandica*) in southeastern Canadian Arctic waters. August- Sept. 1987. Unpublished report for Clearwater Fine Foods, Halifax N.S., Qiqiqtaaluk Corp., Iqaluit NWT, Farocan Inc., Ottawa, Ont., Seaku Fisheries Inc., Montreal, Quebec. Available from Makivik Corp., 650, 32nd ave., 6th floor, Lachine, P.Q. H8T 1Y4.

GILLIS, D.J., M.R. ALLARD, & F. AXELSEN. 1987. Projet des pêcheries de Killiniq. Terr.Phase III. **Société Makivik. Service de la Recherche.** Available from Makivik Corp., 650, 32nd ave., 6th floor, Lachine, P.Q. H8T 1Y4.

GRAINGER, E.H. 1954. Polychaetous annelids of Ungava Bay, Hudson Strait, Frobisher Bay and Cumberland Sound. **J. Fish. Res. Board Can.** 11:507-528.

GRAINGER, E.H. 1955. Echinoderms of Ungava Bay, Hudson Strait, Frobisher Bay and Cumberland Sound. **J. Fish. Res. Board Can.** 12:899-916.

HUDON, C. 1990. Distribution of shrimp and fish by-catch assemblages in the Canadian eastern Arctic in relation to water circulation. **Can. J. Fish. Aquat. Sci.** 47:1710-1723.

HUDON, C., D. PARSONS & R. CRAWFORD. 1990. Diel aspects of shrimp (*Pandalus montagui*) biology: I. Vertical distribution, food and feeding. Unpublished report. Abstract accepted for ICES symposium Moncton, June 1990.

LUBINSKY, I. 1958. Studies on *Mytilus edulis* L. of the "Calanus" expeditions to Hudson Bay and Ungava Bay. **Can. J. Zool.** 36:869-881.

LUBINSKY, I. 1980. Marine bivalve molluscs of the Canadian central and eastern Arctic: faunal composition and zoogeography. **Can. Bull. Fish. Aquat. Sci.** 207. 111 pp.

MACKAY, C.W., 1986. Cumberland Sound test fishing project 1985. Unpublished final report to the Hunters and Trappers Association, Pangnirtung, NWT.

SIMPSON, A.C., B.R. HOWELL, & P.J. WARREB. 1970. Synopsis of biological data on the shrimp *Pandalus montagui* Leach, 1814. **FAO Fish. Rep.** 57:1225-1249.

SINCLAIR, M., R.K. MOHN, G. ROBERT, & D.L. RODDICK. 1985. Considerations for the effective management of Atlantic scallops. **Can. Tech. Rep. Fish. Aquat. Sci.** 1382. 113 pp.

SQUIRES, H.J. 1957. Decapod crustaceans of the "Calanus" expeditions in Ungava Bay, 1947 to 1950. **Can. J. Zool.** 35:463-494.

SQUIRES, H.J. 1966. Distribution of decapod Crustacea in the northwest Atlantic. **Ser. Atlas Mar. Environ.**, Am. Geogr. Soc., Folio 12. 4 pp.

SQUIRES, H.J. 1968. Some aspects of adaptation in decapod Crustacea in the northwest Atlantic. **Fish. Res. Board. Can. Stud.** 1260:215–223.
TAGGART, C.T., K.F. DRINKWATER, K.T. FRANK, J. MCRUER, & P. LAROUCHE. 1989. Larval fish, zooplankton community structure, and physical dynamics at a tidal front. **Rapp. P.-v. Réun. Cons. int. Explor. Mer.** 191:184–194.
WACASEY, J.W. & E.G. ATKINSON. 1987. Benthic invertebrates collected from Ungava Bay, Canada, 1947–1951. **Can. Tech. Rep. Fish. Aquat. Sci.** 1537. 68 pp.
WIBORG, K.F. 1963. Some observations on the Iceland scallop *Chlamys islandica* (Muller) in Norwegian waters. **Fiskdir. Skr. Ser. Havunders.** 13(6):38–53.

DIVERSITY AND BIOLOGY OF INVERTEBRATES AND FISH

D.E. McAllister

Research Curator, Ichthyology Section
National Museum of Natural Sciences
P.O. Box 3443, Station D
Ottawa, Ontario, K1P 6P4

INTRODUCTION

There is much talk about the large number of undescribed species and of the new distribution records waiting to be found in tropical rain forests and coral reefs. However, biologists have been much quieter about the adequacy of taxonomic knowledge about the biota of Canada, particularly that occuring along its enormous Arctic coastline of which Hudson Strait is a part.

BIODIVERSITY AND TAXONOMY OF INVERTEBRATES

Research, conservation and resource management all require adequate and reliable baseline taxonomic, geographic and ecological information. However, we are largely ignorant about the biodiversity, taxonomy and biology of the invertebrate biota of much of Canada, the Arctic and Hudson Strait in particular. By biodiversity I mean the number of species present in a given geographic region. A recent survey of biodiversity in Canada for the upcoming "Status of the Environment" report for Canada concludes that there are 74,363 scientifically described and named non-viral species of animals, plants, and bacteria in terrestrial, aquatic and marine habitats in Canada. The survey conservatively estimates that there are at least 74,450 non-viral species (50.1%) yet to be named, or named but as yet unnrecorded in Canada. As the waters of Hudson Strait are much less completely surveyed than are those to the south we can surmise that probably more than half of the species of benthic invertebrates remain to be discovered, described and named.

How much of the biodiversity of Canada have we studied? We can subdivide biodiversity into the **known**: species discovered, described, given scientific names and recorded from the region in question and the **unknown**: 1) species which actually occur in the region but which have not yet been detected by surveys and which already have scientific name, and 2) species which actually occur in the region and which have not been discovered, described and given new scientific names.

Much of Canada's biota is in the unknown category. More than 99% of the viruses, about 99% of the bacteria, more than 30% of the sea anemones, 20% of the nematodes, 40% of the polychaetes, 75% of the water bears, 20% of the isopods, 45% of the amphipods are still unrecorded or undiscovered and unnamed in Canada and probably in Hudson Strait. Dr. E.L. Bousfield (pers. comm.) estimates that 25% of the Arctic amphipod fauna will still be unknown when his latest Pacific monographic series is completed. Checklists, keys, catalogs, distribution maps, and monographs do not exist for many of these groups, or they are outdated. Some of the invertebrate groups are key-stones in the ecosystem, and yet there has been little research on them. There has been an over-emphasis on a few commercially exploitable species and on the mammals and birds, and far less on the species constituting the lower trophic levels. We can conclude that the baseline knowledge of biodiversity, taxonomy and distribution of Canada's arctic marine organisms is very incomplete.

The geographic distribution of marine invertebrate sampling is very uneven in the Arctic. For example, distribution maps indicate that sampling of molluscs, both gastropods and bivalves, is poorer in Hudson Strait, especially west of Ungava Bay, than in eastern Hudson Bay. Furthermore, in many studies samples were obtained at considerable cost for specific analyses, but in only a few instances were representative samples placed in permanent museum repositories to document distributions or to provide the grist for future monographs and revisions.

TAXONOMY

Another major problem hampering advances in our knowledge of invertebrate biodiversity and marine resources is the lack of specialists for many of the major taxonomic groups. Less than 10 percent of the phyla are served by a curator specialist at the Canadian Museum of Nature (formerly the National Museum of Natural Sciences), and there is only a sparse representation of taxonomists in universities across Canada.

What taxonomic manuals and guides are available for the marine benthic fauna of Hudson Strait and nearby areas of the eastern Arctic? Ignoring those before 1950, the list includes the following:

- BOUSFIELD (1955) - The cirripede crustacea of the Hudson Strait region, Canadian eastern Arctic.
- COREY (1981) - Distribution of certain arctic and subarctic Cumacea in Canadian waters.
- DUNBAR (1954) - The amphipod crustacea of Ungava Bay, eastern Canadian Arctic.
- GRAINGER (1954) - Polychaetous annelids of Ungava Bay, Hudson Strait, Frobisher Bay and Cumberland Sound.
- GRAINGER (1955) - Echinoderms of Ungava Bay, Hudson Strait, Frobisher Bay and Cumberland Sound.
- GRAINGER (1966) - Sea stars (Echinodermata: Asteroidea) of Arctic North America.
- POWELL (1968) - Bryozoa (Polyzoa) of Arctic Canada.
- MACPHERSON (1971) - The marine mollusca of Arctic Canada.
- SHIH *et al.* (1971) - A synopsis of Canadian marine zooplankton.
- LAUBITZ (1972) - The Caprellidae (Crustacea: Amphipoda) of Atlantic and Arctic Canada.
- LUBINSKY (1980) - Marine bivalve molluscs of the Canadian central and eastern Arctic.
- NATIONAL MUSEUM OF NATURAL SCIENCES (1980....) Bibliographia invertebratorum aquaticorum canadensum. (includes indices to generic names, a bibliography, and a compilation of published information by species).

SQUIRES (1957) - Decapod crustacea of the Calanus expeditions in Ungava Bay, 1947 to 1950.
TRASON (1964). Ascidians of the Canadian Arctic waters.

This bibliographic series is far from complete and information on arctic taxa, especially those of Hudson Strait, is generally sparse.

WACASEY & ATKINSON (1987) published a distributional survey of "Benthic invertebrates collected from Ungava Bay, Canada, 1947-1951", and these same authors (1989 a,b and c) published three other regional surveys of arctic invertebrates, covering Hudson Bay, western Arctic Canada, and Hudson Strait-Foxe Channel-Foxe Basin. There are other studies, but overall we can say that more taxonomic groups lack good, complete manuals than possess them in the Canadian Arctic in general and Hudson Strait in particular.

The basic biology of the invertebrate fauna of Hudson Strait is even less well known than is the taxonomy and distribution. There is little or no information on life history, ecology, habitat, reproduction, feeding habits, growth, diurnal and seasonal movements of most species. Canadian university researchers have tended to concentrate on the more southerly waters of the Atlantic and Pacific coasts, and have virtually ignored our longest marine coastline in the Arctic. Much of the biological knowledge about the area must therefore be derived from studies conducted elsewhere in the north. Furthermore, what limited information that is available has largely been collected during the summer; there have been few studies in fall and Spring, and fewer still in winter.

BIODIVERSITY AND TAXONOMY OF FISHES

Fishes are perhaps better known than most other arctic biota, but there are still large gaps in our knowledge. The best regional work on Hudson Strait is still DUNBAR & HILDEBRAND's (1952) "Contribution to the study of fishes of Ungava Bay". My "Bibliography of the marine fishes of Arctic Canada 1771-1985" listed 1,111 references (McALLISTER & STEIGERWALD 1986); about 100 of these papers deal with Hudson Strait. My "List of Inuktitut, French, English and scientific names of marine fishes of Arctic Canada" (McALLISTER 1987) listed 135 species occurring in marine and brackish waters of Arctic Canada. Nomenclature of that list is updated in my (1990) "List of fishes of Canada". "A distributional atlas of records of the marine fishes of Arctic Canada in the National Museums of Canada and Arctic Biological Station" (HUNTER *et al.* 1984) showed 43 species in Hudson Strait. The Atlas did not include literature records and the known fish fauna of Hudson Strait including Ungava Bay might even be as high as 60 species. Certainly there remain a number of species to be discovered and the true biodiversity probably exceeds 75 species. McALLISTER's published and manuscript keys to marine fishes of Arctic Canada are outdated and sorely in need of revision. SCOTT & SCOTT's (1988) "Atlantic fishes of Canada" and ANDRIASHEV's (1954) "Fishes of the northern seas of U.S.S.R." are of some assistance, but a comprehensive book on arctic fishes is badly needed. In addition, the taxonomy of a number of arctic fish groups is in need of further study and revision, e.g. Zoarcidae and Cottidae.

The atlas map of station records of the Arctic Biological Station and the Canadian Museum of Nature indicates that there has been moderate sampling coverage of the shores of Ungava Bay and only modest coverage of the western Baffin coast of Hudson Strait. The atlas also indicates that sampling coverage of the eastern Baffin coast of Hudson Strait, the western Quebec coast of Hudson Strait (west of Ungava Bay), and the deeper waters of Hudson Strait is poor. Recent surveys have improved deeper water sampling coverage somewhat, though only a few of these collections are represented by voucher specimens in museums. Voucher specimens are especially valuable and necessary when taxonomy is unclear or proper identification manuals are not available because field identifications are often unreliable. Extending the variety of sampling methods enables better overall sampling of the biota. Midwater samples, and especially closing - net midwater samples, are poorly represented in our collections. Subtidal sampling by weasel trawls or scuba diving is needed. Use of ichthycides might reveal the presence of previously unrecorded cryptic or nocturnal species.

ENVIRONMENTAL CONCERNS

What impact is man having on the arctic marine environment and fauna? Mercury has been detected in arctic fauna for at least two decades and PCBs for at least 18 years. Their potential effects are just beginning to be fully appreciated now that medical analyses are revealing high levels in our northern native peoples (D.I.N.A 1989). The presence of PCBs in the breast milk of Inuit mothers underlines the extent and significance of pollution of arctic waters. What impacts have the existing James and Hudson basin's hydroelectric schemes had on fishes of Hudson Strait? We know about heightened mercury levels in fishes, but the full impact of changed annual thermal and salinity regimes on inshore and anadromous species remains to be measured. Should we be carrying out baseline biological studies in order to predict and monitor potential impacts of future hydroelectric development of the rivers of Hudson Bay and Ungava Bay? Only by starting early will we have the time to carry out adequate environmental impact studies. McALLISTER (1977) and others have pointed out the dangerous potential impact of arctic and subarctic oil spills on the ice diatom-crustacean-arctic cod food chain. We have all heard about global climatic warming as a result of increases in levels of carbon dioxide in the earth's atmosphere. Some climatic warming studies suggest that the temperature increases will be greatest towards the poles. Some predictions forcast more sea ice, not less. If there is less ice, what effects will increased ice insulation and albedo have in turn on the climate? In addition, increased UV radiation, resulting from the hole in the ozone layer in the Antarctic, is causing a reduction in phytoplankton which may be expected to influence zooplankton, krill, fish and whale populations, not to mention global carbon dioxide and oxygen flow. Will these effects occur in the north polar regions as strongly? What portents do these have for the Arctic? Is anyone really looking in the Arctic? As polar scientists we should be concerned about these environmental changes, and push for more comprehensive studies of key arctic organisms and ecosystems. To conserve and manage our arctic ecosystems in a responsible manner we need to invest heavily in the acquisition of baseline information.

WHAT NEEDS TO BE DONE?

1) A base-line multi-gear grid survey of the fishes needs to be carried out, with representative voucher specimens preserved, otoliths, scales, sizes, weights and stomachs sampled, and relevant environmental parameters recorded. This will permit distribution maps to be plotted which show where the fishes occur, and not, as at present, where the few sampling stations are located. The survey will also provide information about bathymetric, temperature and salinity distributions. The data should be stored in a computerized geographic information system (GIS) and published as an atlas. Voucher material from this and other surveys should be deposited in the Canadian Museum of Nature. The voucher specimens properly collected and preserved will permit taxonomic analyses, preparation of identification manuals and distributions maps, and permit the development of a more solid nomenclature that will assure that data from other scientific studies are ascribed to the correct species. Other samples from the survey would enable food preferences and growth characteristics of fishes to be analyzed.

2) Tissue samples from fishes and other organisms in the food chain should be collected and frozen for analysis of contaminants. Standard stations and methods should be established for periodic monitoring of faunal and floral contaminants. The sources of the toxic material should be determined so that remedial actions can be taken.

3) Studies of the life history, behavior, and ecology of the lesser known fish species should be carried out.

4) Establish an arctic marine biological monitoring program to study the effects of climatic warming and increasing UV radiation.

5) NSERC, DINA, DFO, Canadian Museum of Nature and other appropriate funding agencies should provide scholarships for young Inuit to pursue careers in fisheries, marine biology, and systematics of arctic fauna and flora. The role of native people in managing biodiversity, ecosystems and marine resources need to be affirmed.

6) The marine plant and invertebrate phyla of Canada are very much understudied compared to fishes, birds and mammals. Scholarships, special research grants and new government research positions are needed to rectify this.

7) Establish a permanent marine biological station in the Hudson Strait area, in the western Arctic and in the high Arctic. The role of the DFO Arctic Biological Station at Ste-Anne-de-Bellevue, Quebec, should be affirmed and given enhanced resources to carry out its work. Indecision about its status has undermined its productivity and staff morale.

8) The book "Marine fishes of Arctic Canada" should be completed. Much of the ground work for this publication has already been accomplished at the Canadian Museum of Nature but additional resources are required to complete the analyses, prepare the illustrations and write the text.

REFERENCES

ANDRIASHEV, A.P. 1954. **Fishes of the northern seas of the USSR.** Moskva–Leningrad Izdo–vo Akademii nauk SSR. 566 pp.

ATKINSON, E.G. & J.W. WACASEY. 1989a. Benthic invertebrates collected from Hudson Bay, Canada, 1953 to 1965. **Can. Data Rep. Fish. Aquat. Sci.** 744. 125 pp.

ATKINSON, E.G. & J.W. WACASEY. 1989b. Benthic invertebrates collected from the western Canadian Arctic, 1951 to 1985. **Can. Data Rep. Fish. Aquat. Sci.** 745. 136 pp.

ATKINSON, E.G. & J.W. WACASEY. 1989c. Benthic invertebrates collected from Hudson Strait, Foxe Channel and Foxe Basin, Canada, 1949 to 1970. **Can. Data Rep. Fish. Aquat. Sci.** 746. 102 pp.

BOUSFIELD, E.L. 1955. The cirripede Crustacea of the Hudson Strait region, Canadian eastern Arctic. **J. Fish. Res. Board Can.** 12:762–767.

COREY, S. 1981. Distribution of certain arctic and subarctic Cumacea in Canadian waters. **Can. J. Zool.** 59:1726–1733.

D.I.N.A 1989. **Contaminants in northern ecosystems and native diets.** Summary of an Evaluation Meeting held in Ottawa, February 28 to March 2, 1989. Department of Indian and Northern Affairs Canada. 6 pp.

DUNBAR, M.J. 1954. The amphipod Crustacea of Ungava Bay, Canadian eastern Arctic. **J. Fish. Res. Board Can.** 11:709–798.

DUNBAR, M.J. & HILDEBRAND. 1952. Contribution to the study of fishes of Ungava Bay. **J. Fish. Res. Board Can.** 9(2):83–128.

GRAINGER, E.H. 1954. Polychaetous annelids of Ungava Bay, Hudson Strait, Frobisher Bay and Cumberland Sound. **J. Fish. Res. Board Can.** 11:507–528.

GRAINGER, E.H. 1955. Echinoderms of Ungava Bay, Hudson Strait,Frobisher Bay and Cumberland Sound. **J. Fish. Res. Board Can.** 12:899–916.

GRAINGER, E. H. 1966. Sea stars (Echinodermata: Asteroidea) of Arctic North America. **Bull. Fish. Res. Board Can.** 152. 70 pp.

HUNTER, J.G., LEACH, S., McALLISTER, D.E., & STEIGERWALD, M. 1984. A distributional atlas of records of the marine fishes of Arctic Canada in the National Museums of Canada and Arctic Biological Station. **Syllogeus, National Museums of Canada** 52. 35 pp.

LAUBITZ, D.R. 1972. The Caprellidae (Crustacea: Amphipoda) of Atlantic and Arctic Canada. **Natl. Mus. Nat. Sci., Ottawa, Publ. Biol. Oceanogr.** 4:1–82.

LUBINSKY, I. 1980. Marine bivalve molluscs of the Canadian central and eastern Arctic. **Can. Bull. Fish. Aquat. Sci.** 207. 111 pp.

McALLISTER, D.E. 1977. The ecology of marine fishes of Arctic Canada. Pp. 49–65 *In*: **Proceedings, Circumpolar Conference on Northern Ecology**, September 15–18, 1975, Ottawa. National Research Council of Canada, Ottawa.

McALLISTER, D.E. & M.B. STEIGERWALD. 1986. Bibliography of the marine fishes of Arctic Canada 1771–1985. **Can. MS Rep. Fish. Aquat. Sci.** 1909. 108 pp.

McALLISTER, D.E. 1987. Liste des noms inuktitut (esquimaux), français, anglais et scientifiques des poissons marins du Canada arctique. / List of Inuktitut, French, English and scientific names of marine fishes of Arctic Canada. **Rapport manuscrit canadien des sciences halieutiques et aquatiques.** 1932. 106 pp.

McALLISTER, D.E. 1990. List of fishes of Canada. In press: **Syllogeus** National Museums of Canada 64. 320 pp.

MACPHERSON, E. 1971. The marine mollusca of Arctic Canada. **National Museums of Canada, Publ. Biol. Oceanogr.** 3. 149 pp.

NATIONAL MUSEUM OF NATURAL SCIENCES. 1980+ **Bibliographia invertebratorum aquaticorum canadensum.** National Museum of Natural Sciences, Ottawa.

POWELL, N.A. 1968. Bryozoa (Polyzoa) of Arctic Canada. **J. Fish.Res. Board Can.** 25:2269-2320.

SCOTT, W.B. 1988. Atlantic fishes of Canada. **Can. Bull. Fish. Aquat. Sci.** No. 219:761 pp.

SHIH, C.-T, A.J.G. FIGUEIRA & E.H. GRAINGER. 1971. A synopsis of Canadian marine zooplankton. **Bull. Fish. Res. Board Can.** 176. 264 pp.

SQUIRES, H. J. 1957. Decapod Crustacea of the Calanus expeditions in Ungava Bay, 1947 to 1950. **Can. J. Zool.** 35:463-494.

TRASON, W. 1964. Ascidians of the Canadian arctic waters. **J. Fish. Res. Board Can.** 21:1505-1517.

WACASEY, J.W. & E.G.ATKINSON. 1987. Benthic invertebrates collected from Ungava Bay, Canada, 1947-1951. **Can. Tech. Rep. Fish. Aquat. Sci.** 1537. 68 pp.

SEABIRDS: POPULATIONS, ECOLOGY AND ENERGY CONSUMPTION

Anthony J. Gaston

Canadian Wildlife Service
National Wildlife Research Centre
100 Gamelin Blvd., Hull, Quebec, K1A 0H3

The Canadian Wildlife Service has carried out studies of marine birds in Hudson Strait and northern Hudson Bay since 1953. Most of this work has entailed the censusing and banding of colonially breeding seabirds in order to assess the impact of hunting and the effects of offshore oil developments in their wintering areas off Newfoundland and Labrador. Particular attention has been devoted to the thick-billed murre *Uria lomvia* (TUCK 1961, GASTON *et al.* 1983) and the common eider *Somateria mollissima* (REED 1986).

Previous reviews of marine birds in the area were provided by BROWN *et al.* (1975), who mapped the major seabird colonies, BROWN (1986), who mapped the distribution of birds at sea, based on observations from ships, and MORRISON & GASTON (1986) who gave distribution maps for several non-colonial species. TODD (1963) gave an account of the seabirds of the Ungava Peninsula, MACPHERSON & MCLAREN (1959) described the seabirds of the Foxe peninsula, and GASTON *et al.* (1985) gave a detailed description of the seabird community of Digges Sound. GASTON *et al.* (1986) mapped distributions of most seabird species for northern Hudson Bay and Foxe Basin. References to earlier accounts of breeding seabirds in the area can be found in these sources.

Considering the large area of marine waters involved, the variety of seabirds using them is relatively small. Species characteristic of the rich seabird community found in subarctic waters off Newfoundland and Labrador; Leach's storm-petrel *Oceanodroma leucorhoa*, great shearwater *Puffinus gravis*, northern gannet *Sula bassana*, common murre *Uria aalge*, razorbill *Alca torda* and atlantic puffin *Fratercula arctica*, reach Hudson Strait, if at all, only in insignificant numbers. Black-legged kittiwakes, which are abundant in Southeast Newfoundland and the Gulf of St. Lawrence, and are present alongside thick-billed murres at all the colonies in Lancaster Sound, do not occur at any of the four murre colonies within Hudson Strait. About 5000 pairs breed alongside thick-billed murres on Hantzsch Island, just off the northeast coast of Edgell Island, and a few small colonies occur around Resolution Island, but the breeding distribution of the species stops abruptly at the eastern end of the Strait. Northern fulmars *Fulmarus glacialis*, which breed in large numbers throughout Davis Strait and Lancaster Sound, are likewise absent from Hudson Strait as breeders.

Using counts of birds made from ships, the diversity of seabirds in the offshore waters of Hudson Strait in July is much lower than that observed in adjacent marine areas (Table 5). This is despite the fact that such counts include non-breeding birds of species that do not nest in Hudson Strait. No satisfactory explanation for the low diversity of seabirds in Hudson Strait has been proposed (GASTON 1982).

Table 5. Species diversity (Shannon-Weaver statistic H') of seabirds in Hudson Strait and adjacent marine areas*.

AREA	H'	SPECIES
Southern Davis Strait (60-65° N)	0.81	10
Northern Labrador Banks (55-60° N)	1.07	16
Labrador Sea (ex. the continental shelf)	1.00	14
Hudson Strait & NE Hudson Bay	0.55	8
Rest of Hudson Bay	1.09	4

* Based on counts made from ships in offshore waters in July. From data supplied by R.G.B. Brown from the C.W.S. PIROP database (BROWN *et al.* 1975).

Despite the low diversity of species breeding, the area does support significant numbers of several seabirds. The iceland gull *Larus glaucoides* is of particular interest because the population of Hudson Strait makes up a significant fraction of the global population of this rather scarce bird. In addition, the majority of thick-billed murres breeding in the Western Atlantic do so in, or close to, Hudson Strait. This species has declined in parts of its Atlantic range over the past several decades (EVANS 1984; EVANS & NETTLESHIP 1985), but populations in Hudson Strait appear to be stable at present. Other abundant species of coastal waters, particularly along the north coast of Hudson Strait and in Ungava Bay, are the common eider *Somateria mollissima* (CHAPDELAINE & TREMBLAY 1979; papers in REED 1986) and the black guillemot *Cepphus grylle* (NETTLESHIP & EVANS 1985). The king eider *Somateria spectabilis* occurs along the north coast in large numbers on spring migration (MACPHERSON & MCLAREN 1959), but only a few breed in the area. Breeding populations in Hudson Strait, including the colonies at Hantzsch Island and Coats Island, are summarized in Table 6.

Non-breeding seabirds occur in some numbers within Hudson Strait, particularly in August and September. Northern fulmars concentrate around the eastern entrance to the Strait from mid-July onwards, with a peak in late August and September. They are very numerous off Resolution Island, and abundant as far west as Big Island, but they are seen in only small numbers in the western part of the Strait (MACLAREN MAREX 1979; BROWN 1986). Black-legged kittiwakes are found in small numbers throughout the Strait, but are most numerous at the eastern end (BROWN 1986). They are very abundant around the Button Islands and Resolution Island in late August and September (MACLAREN MAREX 1979). Dovekies *Alle alle* occur at low densities in the eastern half of the Strait from July to

Table 6. Seabird populations (pairs) breeding in, or adjacent to, Hudson Strait. Sources: BROWN *et al.* (1975); NETTLESHIP & EVANS (1985); GASTON *et al.* (1985, 1986).

SPECIES	DISTRIBUTION	POPULATION
Common eider (*Somateria mollissima*)	Throughout the strait, but especially the north shore and Ungava Bay.	50,000 - 100,000
Herring gull (*Larus argentatus*)	Common on islands in Ungava Bay, but uncommon elsewhere.	4000 - 5000
Iceland gull (*Larus glaucoides*)	Colonies of up to 200 pairs scattered on north coast, on Nottingham and Salisbury Islands, and around Digges Sound.	1000 - 3000
Great Black-backed gull (*Larus marinus*)	Scattered pairs on the east coast of Ungava Bay.	< 500
Glaucous gull (*Laurus hyperboreus*)	Pairs or small colonies, often with Iceland Gulls, throughout the Strait, except Ungava Bay. Larger colonies in association with murres at Akpatok Island and Digges Sound.	< 2000
Black-legged kittiwake (*Rissa tridactyla*)	Small colonies on Meta Incognita Peninsula, the Button Islands and Resolution Island. 5000 pairs on Hantzsch Island.	c. 5000
Arctic tern (*Sterna paradisaea*)	An uncommon breeder in Hudson Strait, usually on islands in lakes adjacent to the coast.	< 500
Thick-billed murre (*Uria lomvia*)	Very numerous, breeding in large colonies at:	c. 900,000
	Hantzsch Island	50,000
	Akpatok Island	520,000
	Digges Sound	300,000
	Coats Island	25,000
Razorbill (*Alca torda*)	Scattered birds have been seen in the breeding season, but breeding has not been proven.	very few
Atlantic puffin (*Fratercula arctica*)	A small colony exists near Digges Sound and there may be a few other birds breeding in the Strait.	< 100
Black guillemot (*Cepphus grylle*)	Common throughout the Strait, and breeding in colonies of up to 1000 pairs.	20,000 - 40,000

October.

The majority of seabirds leave Hudson Strait by October, returning as the winter ice cover begins to break up, in May or early June. Black guillemots, however, make use of small leads and patches of open water among dense pack. It is possible that most of the black guillemots breeding in Hudson Bay and Hudson Strait remain in those waters throughout the winter (GASTON & MCLAREN in press). Likwise, common eiders winter in Hudson Bay, where tidal currents maintain polynyas, and small numbers also winter in Hudson Strait, particularly around the eastern entrance (ABRAHAM & FINNEY 1986). By April large numbers are present in flaw leads along the north coast of Hudson Strait and around Meta Incognita Peninsula (MACLAREN MAREX 1979; GASTON & COOCH 1986).

Seabird biomass in the summer has been computed from counts made at sea and

Table 7. Energy use (10^6 kJoules/km^2) by seabirds in Hudson Strait during July and August compared to adjacent marine areas (from DIAMOND 1985).

AREA	JULY	AUGUST
Southern Davis Strait (60-65^o N)	0.2	1.4
Northern Labrador Banks (55-60^o N)	0.4	1.0
Labrador Sea (ex. the continental shelf)	0.4	1.0
Hudson Strait & NE Hudson Bay	1.1	0.5
Rest of Hudson Bay	0.2	<0.1

the total food requirement of this density of seabirds has been estimated from allometric equations based on body mass (DIAMOND 1985). In July, thick-billed murres comprise 95% of the energy demand by offshore-feeding seabirds in Hudson Strait, which totals 1.08 * 10^6 kJoules km^{-2}. This figure is five times that estimated for Hudson Bay, and more than four times that for southern Davis Strait (Table 7). In August the estimated energy requirement falls to 0.5 * 10^6 kJoules km^{-2}, ten times that estimated for Hudson Bay, but only half that for southern Davis Strait, where non-breeding and post-breeding birds concentrate during late August. From the estimates of energy consuption and the known energy content of prey I estimate that seabirds remove 70,000 metric tons fresh mass of prey during June-August, equivalent to 0.36 g m^{-2}.

As thick-billed murres dominate energy transfer to seabirds in Hudson Strait, it seems appropriate to examine their diet in detail. The diets of breeding adults collected around Digges Sound were analysed by GASTON & NOBLE (1985), and those of chicks by GASTON (1985, 1987). Adult diets throughout the eastern Arctic have been reviewed by BRADSTREET & GASTON (in press). The most common food identified in stomachs of adult murres collected in Hudson Strait was the amphipod *Themisto libellula*, while crustacea of the genera *Mysis*, *Thysanoessa* and *Nantantia*, annelids, the squid *Gonatus fabricii*, arctic cod *Boreogadus saida*, sand lance *Ammodytes* spp. and snailfish *Liparis* spp. all occurred in more than 25% of stomachs in at least one year. At Akpatok Island in 1983 nine out of 19 stomachs contained remains of the Greenland halibut *Rheinhardtius hippoglossoides*, but this species was never recorded in birds collected around Digges Sound.

Practically all the food delivered to thick-billed murre chicks consisted of fish, with arctic cod being the most common species, especially at Digges Sound, where it comprised more than 50% of items delivered. Arctic cod were the commonest fish delivered at all colonies except Hantzsch Island, where sculpins, mostly *Triglops* spp., predominated. At Coats Island in one season capelin *Mallotus villosus* made up more than 25% of items, but otherwise no single species accounted for more than 15% of the diet.

Recent investigations, using depth gauges strapped to the backs of breeding birds, have shown that thick-billed murres can feed at depths below 100 m, but that an average dive takes them to 20-40 m (D. Croll, pers. comm.). Dives tend to be shallowest at night, when most birds do not descend below 20 m. Feeding is more intensive during the night than in the middle of the day, suggesting that prey organisms are more readily available when it is dark. This may be because the prey are closer to the surface at night than during the day, but little information is available on the behaviour of the prey.

Because they are extremely active and turn over energy very quickly, seabirds are very sensitive to changes in the distribution and abundance of their food supplies. Thick-billed murres forage as much as 150 km from their colonies and hence studying their behaviour and reproduction can integrate information from a very wide area. Easily observed behaviour such as the length of incubation shifts, the amount of time spent on the colony by non-breeders and off-duty breeders, and the rates at which chicks are fed, respond more or less immediately to changes in food availability. Hence, seabirds provide an excellent tool for monitoring changes in the marine environment. In addition, examination of the stomach contents of thick-billed murres is a useful way to sample fish and zooplankton. Such data can be interpreted more easily than hitherto, thanks to the recent development of depth gauges, allowing us to obtain a better understanding of exactly what part of the water column is being sampled by the murres. There is excellent scope to expand collaboration between marine ornithologists and other marine biologists and Hudson Strait looks like a good place to do it.

REFERENCES

ABRAHAM, K.F. & G.H. FINNEY. 1986. Eiders of the eastern Canadian Arctic. Pp. 55-73 *In*: Reed, A. (ed) **Eider Ducks in Canada**. Can. Wildlife Serv. Rep. Ser. 47.

BROWN, R.G.B. 1986. **Revised atlas of eastern Canadian seabirds. 1 Shipboard surveys**. Can. Wildlife Serv. Ottawa. 111 pp.

BROWN, R.G.B., D.N. NETTLESHIP, P. GERMAIN, C.E. TULL & T. DAVIS. 1975. **Atlas of eastern Canadian seabirds**. Can. Wildlife Serv. Ottawa: 220 pp.

CHAPDELAINE, G. & G. TREMBLAY. 1979. Distribution and abundance of Eider Duck (*Somateria mollissima sedentaria* and *S. m. borealis*) along the coasts of Hudson Bay, Hudson Strait and Ungava Bay. **Can. Wildlife Serv. MS. Report** (unpubl.)

DIAMOND, A.W. 1985. A computer model of the energy demands of the seabirds of eastern and Arctic Canada. **Can. Wildlife Serv. MS. Report**. 94 pp.

EVANS, P.G.H. 1984. The seabirds of Greenland: their status and conservation. Pp. 49-84 *In*: Croxall, J.P., P.G.H. Evans & R.W. Schreiber (eds). **Status and Conservation of the World's Seabirds**. International Council for Bird Preservation Tech. Publ. 2.

EVANS, P.G.H. & D.N. NETTLESHIP. 1985. Conservation of the Atlantic Alcidae. Pp. 427-488 *In*: Nettleship, D.N. & T.R. Birkhead (eds). The Atlantic Alcidae. Academic Press, Orlando, Fl.

GASTON, A.J. 1982. On the seabirds of northern Hudson Bay. **Naturaliste can. (Rev. Ecol. Syst.)** 109:895-903.

GASTON, A.J. 1985. The diet of Thick-billed Murre chicks in the eastern Canadian Arctic. **Auk** 102:727-734.

GASTON, A.J. 1987. Length and weight of fish delivered by Thick-billed Murres to their chicks at Digges, Coburg and Coats Islands, N.W.T., 1980-1987. **Can. Wildlife Serv. Tech. Rep. Ser.** 5. 13 pp.

GASTON, A.J., D.K. CAIRNS, R.D.ELLIOT & D.G.NOBLE. 1985. A natural History of Digges Sound. **Can. Wildlife Serv. Rep. Ser.** 46. 63 pp.

GASTON, A.J., G. CHAPDELAINE & D.G. NOBLE. 1983. The growth of Thick-billed Murre chicks at colonies in Hudson Strait: inter -and intra-colony effects. **Can. J. Zool.** 61:2465-2475.

GASTON, A.J. & F.G. COOCH. 1986. Observations of Common Eiders in Hudson Strait: aerial surveys in 1980-83. Pp. 51-54 *In*: Reed, A. (ed). Eider Ducks in Canada. **Can. Wildlife Serv. Rep. Ser.** 47.

GASTON, A.J., R. DECKER, F.G. COOCH & A. REED. 1986. The distribution of larger species of birds breeding on the coasts of Foxe Basin and northern Hudson Bay, Canada. **Arctic** 39:285-296.

GASTON, A.J. & P.L. MCLAREN. 1990. Winter observations of Black Guillemots in Hudson Bay and Davis Strait. Studies in Avian Biology. (in press)

GASTON, A.J. & D.G. NOBLE. 1985. The diet of Thick-billed Murres (*Uria lomvia*) in west Hudson Strait and northeast Hudson Bay. **Can. J. Zool.** 63:1148-1160.

MACPHERSON, A.M. & I.A. MCLAREN. 1959. Notes on the birds of southern Foxe Peninsula, Baffin Island, Northwest Territories. **Can. Field-Nat.** 73:63-81.

MACLAREN MAREX. 1979. Report on aerial surveys of birds and marine mammals in the southern Davis Strait between April and December 1978. Report to Esso Resources Canada Ltd., Aquitaine Co. of Canada, Ltd., and Canada Cities Services Ltd. **Arctic Petroleum Operators Association Project**. 146 pp.

MORRISON, R.I.G. & GASTON, A.J. 1986. Marine and coastal birds of James Bay, Hudson Bay and Foxe Basin. Pp. 355-386 *In*: Martini, I.P. (ed.) **Canadian Inland Seas**. Elsevier, New York.

NETTLESHIP, D.N. & EVANS, P.G.H. 1985. Distribution and status of the Atlantic Alcidae. Pp. 54-155 *In*: Nettleship, D.N. and T.R. Birkhead (eds). **The Atlantic Alcidae**. Academic Press, Orlando, Fl.

REED, A. 1986. Eider ducks in Canada. **Can. Wildlife Serv. Rep. Ser.** 47. 177 pp.

TODD, W.E.C. 1963. **The birds of the Labrador Peninsula and adjacent areas.** Toronto Univ. Press, Toronto.

TUCK, L.M. 1961. The Murres. **Can. Wildlife Serv. Monograph.** 1. 260 pp.

MARINE MAMMALS

A.W. Mansfield

Department of Fisheries and Oceans
Arctic Biological Station
555 boul. St-Pierre
Ste-Anne-de-Bellevue, Québec, H9X 3R4

Hudson Strait and Ungava Bay provide extensive habitat for four species of pinnipeds,the walrus, ringed seal, bearded seal, and harp seal, and limited habitat for a rare fifth species, the harbour seal. Four species of cetaceans are also found there, the bowhead, the white whale or beluga, the narwhal and, occasionally, the minke whale. With the exception of the harbour seal and minke whale, which are boreal rather than arctic species, all of these marine mammals have been hunted extensively by the Inuit for thousands of years and several have been exploited commercially.

Our earliest knowledge of marine mammals in this area comes from the American and Scottish whalers who hunted bowhead whales along the south shore of Baffin Island from the 1860s until 1915 (EBER 1989). This was a much smaller and less certain undertaking than the bowhead whale fisheries in Hudson Bay and southeastern Baffin Island because the whales were using Hudson Strait as a seasonal migration route into and out of Hudson Bay and were not usually found there in the open-water season (ROSS 1974; REEVES *et al.* 1983). Whaling virtually ceased after 1915, by which time the population of bowhead whales in the eastern Canadian Arctic had been reduced to a remnant of its former size (MANSFIELD 1971; MITCHELL & REEVES 1981). Since that time low-level but persistent hunting by the Inuit may have inhibited the eastern Arctic population from increasing (MITCHELL & REEVES 1982). In recent years a few bowheads, which may represent the remnant of the Hudson Bay stock, have been seen in the pack ice of Hudson Strait in winter (MCLAREN & DAVIS 1982). Their diet at this time of year is unknown, though it would most likely consist of small and medium sized zooplankton, particularly copepods and euphausids (REEVES & LEATHERWOOD 1985).

Belugas and walruses were sought by the whalers when bowheads were scarce, but catches of these species in Hudson Strait were likely very small. Catches of belugas increased significantly when the Hudson's Bay Company began erecting trading posts and exploiting local populations for their oil and skins (FRANCIS 1977). Largest catches were in southern Ungava Bay where several thousand belugas were taken in the peak period 1877 - 1897 (FINLEY *et al.* 1982; REEVES & MITCHELL 1987).

The beluga is particularly amenable to over-exploitation owing to its ingrained habit of returning to the same river estuary year after year (CARON 1987). This movement into comparatively warm, less-saline water has been interpreted as primarily a means of conserving energy and minimizing the thermal loss for newborn calves (BRODIE 1989). It also appears to aid in the sloughing off of the yellowing outer layers of the epidermis in adult animals (FINLEY 1983; ST. AUBIN *et al.* 1990). Belugas feed on a wide variety of organisms, including molluscs, fish, annelids, decapods and large zooplankton.

Comparatively few belugas are taken in Hudson Strait since the population there is largely migratory (FINLEY *et al.* 1982; REEVES & MITCHELL 1987). In winter, when ice conditions generally preclude hunting, large numbers of belugas are found in Hudson Strait and Ungava Bay, often in the densest pack-ice. Estimates of numbers provided by aerial surveys suggest a winter population in the order of 10,000 belugas (FINLEY *et al.* 1982). Since virtually no other belugas have been seen in Hudson Bay at this time, it appears highly likely that most of these animals represent the Western Hudson Bay stock that is found primarily in the estuaries of the Nelson, Churchill and Seal rivers in summer. It is also likely that some of the belugas seen in Hudson Strait and Ungava Bay in winter represent those found in southeastern Baffin Island, particularly Cumberland Sound, and southern Ungava Bay in summer. The latter population is in critical condition at the present time (REEVES & MITCHELL 1987). The Inuit have continued to exploit it in spite of its rapid decline, and recent surveys indicate that the population has been all but eliminated (SMITH & HAMMILL 1986).

The other truly arctic whale species, the narwhal, is occasionally taken by the Inuit of Lake Harbour and Cape Dorset, but its appearance is sporadic. The relationship of narwhals seen in Hudson Strait in winter (MACLAREN MAREX 1979; MCLAREN & DAVIS 1982) to those found in summer in the Repulse Bay area of northwestern Hudson Bay and in Baffin Bay and Lancaster Sound is uncertain.

Among the pinnipeds, the walrus has always been of prime importance to the Inuit, both for its impressive store of oil and meat and for its tough, resilient hide and ivory tusks. The whalers and the traders were quick to realize the economic importance of this animal. Walruses found in Ungava Bay and along the southern shores of Hudson Strait were thought to be migrants from the east by FREUCHEN (1935) and LOUGHREY (1959). There is some evidence that walruses wintered in Ungava Bay near Akpatok Island (ELTON 1942), and DUNBAR (1955) referred to their being common in summer at the Gyrfalcon Islands in southwest Ungava Bay. At present, numbers appear to be small in both Ungava Bay and most of Hudson Strait, and the only regular hunting is carried out in western Hudson Strait at Nottingham and Salisbury islands in the fall, and occasionally at the floe-edge southeast of Cape Dorset in the winter. These western Hudson Strait walruses are likely part of the same stock that frequents Coats Island and southeastern Southampton Island in the summer, but this has yet to be proven.

The Hudson's Bay Company sought skins and ivory from the Inuit, a practice that probably led to a marked decrease in walrus populations everywhere. Regulations prohibiting the export of skins and ivory from the Northwest Territories were promulgated by the Federal Government in 1931, but local walrus populations have continued to be hard-pressed since that time. The recent acquisition by the Inuit of several small, general purpose vessels as part of the financial settlement under the James Bay and Northern Quebec Agreement, has provided them with the means to reduce the western Hudson Strait walrus population still further. However, hunting pressure may have stabilized or even decreased as a result of a recent outbreak of trichinosis among the Inuit of Ivujivik and Salluit, evidently caused by their eating infected walrus meat (VIALLET *et al.* 1986; TANNER *et al.* 1987).

Few walruses are found elsewhere in Hudson Strait. Small numbers are seen in winter in the pack-ice, particularly in the area between Cape Dorset and Fair

Ness, and some have been seen south of Akpatok Island (MCLAREN & DAVIS 1982), but they have never been subject to much hunting at this time of year.

Like belugas, walruses return to the same summering areas year after year, hauling out on the land at traditional sites. This habit, which is probably linked to the local availability of benthic molluscs, the walruses' primary food, has been a major factor in allowing ready exploitation of this species in western Hudson Strait and northern Hudson Bay. On the positive side, however, the habit provides the biologist with the opportunity to count the animals effectively. Aerial and land-based surveys carried out in 1976 and 1977 provided a minimal estimate of 2,400 walruses in the Coats Island- Southampton Island area (MANSFIELD & ST. AUBIN, unpublished data).

In spite of the importance of the walrus to the Inuit, the mainstay of their economy has always been the ringed seal.This species is found throughout Hudson Strait and Ungava Bay, but it is particularly numerous in southwestern Baffin Island from Cape Dorset to Fair Ness where the complexity of the coastline provides ideal conditions for the development of stable fast ice. As MCLAREN (1958) showed in his pioneering study of ringed seals in this area, the quality and quantity of fast ice are the prime determinants in the distribution and abundance of ringed seals throughout the Arctic. More recent studies by SMITH (1973, 1987) and HAMMILL & SMITH (1989) have extended this theme in great detail and shown how the ringed seal exploits the fast ice so successfully and why it has never suffered any serious depletion, except very locally, in spite of a constant demand for its skin as an item of trade. Food is evidently not a major factor in limiting the distribution of the ringed seal since it feeds on a wide variety of pelagic and epibenthic species, the most important of which are *Mysis oculata*, *Themisto libellula*, and *Boreogadus saida* (MCLAREN 1958; SMITH 1987).

The bearded seal, a resident of the pack ice and a feeder on epibenthic decapods, pelecypods, holothuroideans and fish (SMITH 1981), is widely scattered in distribution and has therefore never been obtained in large numbers; thus comparatively little knowledge of its life history has been obtained over the years (MCLAREN 1958; SMITH 1981). It has also rarely been exploited commercially in view of its importance to the Inuit, who have traditionally used its tough and resilient hide for the manufacture of boot soles and rawhide line. It has been of particular importance to the Inuit of Ungava Bay and Hudson Strait, as revealed by recorded catches which are generally larger than elsewhere in the Canadian Arctic (SMITH 1981).

A summer migrant to Hudson Strait and possibly Ungava Bay is the harp seal. This species, which tends to travel in small groups, is fast-moving and difficult to hunt and has never been of much importance to the Inuit in this area. In view of the long-continued commercial seal hunt off the east coast of Canada, harp seals may never have been present in Hudson Strait in large numbers in the last 200 years, and there is no tradition of their being hunted by the Inuit. However, the demise of the east coast sealing industry in recent years, largely caused by a ban on the importation of seal skins imposed by the European Economic Community (ROYAL COMMISSION ON SEALS AND THE SEALING INDUSTRY IN CANADA 1986), has no doubt allowed the harp seal population to expand again (ROFF & BOWEN 1986), and increasing numbers can be expected to migrate through Hudson Strait in the summer and fall. The species clearly represents a major resource that the

Inuit should be encouraged to exploit. The principal food organisms consumed by harp seals in the Canadian Arctic are arctic cod, mysids, amphipods (particularly *Themisto libellula*) and euphausids (SERGEANT 1973), and they undoubtedly consume capelin when present since this is a preferred food of harp seals in western Greenland.

The remaining pinniped to be found in Hudson Strait and Ungava Bay is the harbour seal. This is a rare species that occurs only in very specific localities where tide rips and swift currents provide ice-free areas in the winter. It is occasionally found in southwestern Foxe Peninsula, near Cape Dorset (MANSFIELD 1967), and is still taken in small numbers by the Inuit in southern Ungava Bay. It has a predilection for freshwater, a habit that has led to its occupying river and lake systems often far from the sea (MANSFIELD 1967; BECK *et al*. 1970). A small population, first described by DOUTT (1942), still exists inland in Lacs des Loups Marins (Lower Seal Lake) at the headwaters of the Nastapoka River. Evidence from the potental fish yield of this system (POWER & GREGOIRE 1978) suggests that a population of about 200 seals could be supported, but it is likely that the number present is far smaller than this. A few harbour seals have been seen in Lacs des Loups Marins in recent years (SMITH & HORONOWITSCH 1987) and further studies will be attempted in view of the proposed development of this whole area under Phase II of the James Bay Hydro-electric Development Project.

REFERENCES

BECK, B., T.G. SMITH & A.W. MANSFIELD. 1970. The occurrence of the harbour seal, *Phoca vitulina*, Linnaeus in the Thlewiaza River, N.W.T. **Can. Field-Nat.** 84: 297-300.

BRODIE, P.F. 1989. The white whale *Delphinapterus leucas* (Pallas, 1776). pp. 119-144 *In* S.H. Ridgway and Sir Richard Harrison (eds). **Handbook of Marine Mammals**, Vol. 4. Academic Press.

CARON, L.M.J. 1987. Status, site fidelity, and behavior of a hunted herd of white whales (*Delphinapterus leucas*) in the Nastapoka estuary, eastern Hudson Bay. **McGill University, M.Sc. thesis**, 136 pp.

DOUTT, J.K. 1942. A Review of the Genus *Phoca*. **Annals Carnegie Museum** 29: 61-125.

DUNBAR, M.J. 1955. The status of the Atlantic walrus, *Odobenus rosmarus* (L), in Canada. **Arctic Circular** 8(1):11-14.

EBER, D.H. 1989. **When the whales were up North**. McGill-Queen's University Press, 187 pp.

ELTON, C. 1942. **Voles, mice and lemmings**. Oxford, Clarendon Press, 496 pp.

FINLEY, K.J. 1983. The estuarine habit of the beluga or white whale (*Delphinapterus leucas*). **Cetus** 4(2):4-5.

FINLEY, K.J., G.W. MILLER, M. ALLARD, R.A. DAVIS & C.R. EVANS. 1982. The belugas (*Delphinapterus leucas*) of northern Quebec: distribution, abundance, stock identity, catch history and management. **Can. Tech. Rep. Fish. Aquat. Sci.** 1123. 57 pp.

FRANCIS, D. 1977. Whaling on the Eastmain. **Beaver**, Outfit 308(1):14-19.

FREUCHEN, P. 1935. Mammals, Part II. Field notes and biological observations. **Rep. 5th. Thule Exped. 1921-24**, 2(4-5):235-251.

HAMMILL, M.O. & T.G. SMITH. 1989. Factors affecting the distribution and abundance of ringed seal structures in Barrow Strait, Northwest Territories. **Can. J. Zool.** 67(9):2212-2219.

LOUGHREY, A.G. 1959. Preliminary investigation of the Atlantic Walrus *Odobenus rosmarus rosmarus* (Linnaeus). **Can. Wildlife Serv., Wildlife Management Bull.** Ser. 1, 14. 123 pp.

MACLAREN MAREX INC. 1979. Report on aerial surveys of marine mammals and birds in southern Davis Strait and eastern Hudson Strait in March, 1978. Report prepared for ESSO Resources Canada Ltd., Aquitaine Co. of Canada Ltd. and Canada Cities Services Ltd. **Arctic Petroleum Operators Association Project.** 146 pp.

MANSFIELD, A.W. 1967. Distribution of the harbor seal, *Phoca vitulina* Linnaeus, in Canadian arctic waters. **J. Mammal.** 48(2):249-257.

MANSFIELD, A.W. 1971. Occurrence of the bowhead or Greenland right whale (*Balaena mysticetus*) in Canadian arctic waters. **J. Fish. Res. Board Can.** 28:1873-1875.

MCLAREN, I.A. 1958. The biology of the ringed seal (*Phoca hispida* Schreber) in the eastern Canadian Arctic. **Bull. Fish. Res. Board Can.** 118. 97 pp.

MCLAREN, P.L. & R.A. DAVIS. 1982. Winter distribution of arctic marine mammals in ice-covered waters of eastern North America. Report prepared for Petro-Canada Exploration, Inc. by **LGL Ltd., Environmental Research Associates**, Toronto. 151 pp.

MITCHELL, E. & R.R. REEVES. 1981. Catch history and cumulative catch estimates of initial population size of cetaceans in the eastern Canadian Arctic. **Rep. Int. Whal. Commn** 31:645-682.

MITCHELL, E.D. & R.R. REEVES. 1982. Factors affecting abundance of bowhead whales *Balaena mysticetus* in the eastern Arctic of North America, 1915-1980. **Biol. Conserv.** 22(1):55-72.

POWER, G. & J. GREGOIRE. 1978. Predation by freshwater seals on the fish community of Lower Seal Lake, Quebec. **J. Fish. Res. Board Can.** 35(6):844-850.

REEVES, R., E. MITCHELL, A. MANSFIELD & M. MCLAUGHLIN. 1983. Distribution and migration of the bowhead whale, *Balaena mysticetus*, in the eastern North American Arctic. **Arctic** 36(1):5-64.

REEVES, R.R. & S. LEATHERWOOD. 1985. Bowhead whale *Balaena mysticetus* Linnaeus, 1758. p. 305-344 *In*: Ridgway, S.H. & Sir Richard Harrison (eds). **Handbook of Marine Mammals**, Vol. 3. Academic Press.

REEVES, R.R. & E. MITCHELL. 1987. Catch history, former abundance, and distribution of white whales in Hudson Strait and Ungava Bay. **Naturaliste can. (Rev. Ecol. Syst.)** 114(1):1-65.

ROFF, D. & W.D. BOWEN. 1986. Further analysis of population trends in the Northwest Atlantic harp seal (*Phoca groenlandica*) from 1967 to 1985. **Can. J. Fish. Aquat. Sci.** 43:553-564.

ROSS, W.G. 1974. Distribution, migration, and depletion of bowhead whales in Hudson Bay, 1860 to 1915. **Arctic & Alpine Res.** 6(1):85-98.

ROYAL COMMISSION ON SEALS AND THE SEALING INDUSTRY IN CANADA. 1986. **Seals and sealing in Canada** (Chairman: Justice A.H. Malouf). 3 vols. Minister of Supply and Services Canada.

SERGEANT, D.E. 1973. Feeding, growth and productivity of Northwest Atlantic harp seals (*Pagophilus groenlandicus*). **J. Fish. Res. Board Can.** 30:17-29.

SMITH, T.G. 1973. Population dynamics of the ringed seal in the Canadian eastern Arctic. **Bull. Fish. Res. Board Can.** 181. 55 pp.

SMITH, T.G. 1987. The ringed seal, *Phoca hispida*, of the Canadian western Arctic. **Can. Bull. Fish. Aquat. Sci.** 216. 81 pp.

SMITH, T.G. 1981. Notes on the bearded seal, *Erignathus barbatus*, in the Canadian Arctic. **Can. Tech. Rep. Fish. Aquat. Sci.** 1042. 49 pp.

SMITH, T.G. & G. HORONOWITSCH. 1987. Harbour seals in the Lacs des Loups Marins and eastern Hudson Bay drainage. **Can. Tech. Rep. Fish. Aquat. Sci.** 1536, 17 pp.

ST. AUBIN, D.J., T.G. SMITH & J.R. GERACI. 1990. Seasonal epidermal molt in beluga whales, *Delphinapterus leucas*. **Can. J. Zool.** 68(2):359-367.

TANNER, C.E., M. STAUDT, R. ADAMOWSKI, M. LUSSIER, S. BERTRAND & R.K. PRICHARD. 1987. Seroepidemiological study for five different zoonotic parasites in Northern Quebec. **Can. J. Public Health.** 78:262-266.

VIALLET, J., J.D. MACLEAN, C.A. GORESKY, M. STAUDT, G. ROUTHIER & C. LAW. 1986. Arctic trichinosis presenting as prolonged diarrhea. **Gastroenterology** 91:938-946.

L'EXPLOITATION ET LA GESTION DES RESSOURCES MARINES

Mimi Breton

MPO, Région du Québec
Division de la Répartition de la Ressource
Gare Maritime Champlain
C.P. 15,500, 901 Cap Diamant
Québec, Québec, G1K 7Y7

INTRODUCTION

Puisque la définition d'un programme de recherche doit non seulement prendre en considération les intérêts purement scientifiques mais aussi ceux d'ordre pratique ou appliqué, comme le développement des pêches et la conservation des ressources, il est nécessaire de connaître les priorités du secteur dit de "gestion des ressources". L'exposé fera donc un survol du contexte politique de l'Arctique canadien, une revue de l'exploitation courante des ressources marines dans le Nord québécois, plus spécifiquement dans le détroit d'Hudson, ainsi que des diverses initiatives de développement des pêches dans les eaux marines périphériques. Les problèmes de gestion et de conservation des ressources et de leur habitat seront également identifiés. En conclusion, dans chacun des domaines abordés seront dégagées les orientations ou priorités actuelles.

CONTEXTE POLITIQUE
ENTENTES

Au Canada arctique, l'exploitation et la gestion des ressources fauniques et de leur habitat sont régies dans le cadre d'ententes définissant les droits et obligations des divers intervenants (Fig. 17). La région du détroit d'Hudson est touchée par la revendication du Tungavit Federation of Nunavut, l'Entente de la Baie James et du Nord québécois ainsi qu'une revendication couvrant la zone hauturière. Par ailleurs, divers règlements s'appliquent à cette région, dont celui sur les pêches des Territoires du Nord-Ouest et celui sur les pêches de l'Atlantique, le 70^{e} parallèle délimitant le champ d'application de ce dernier.

La mise en oeuvre des ententes prévoit, entre autres, l'application du principe de conservation défini comme suit:

> "conservation", la recherche de la productivité naturelle optimale de toutes les ressources vivantes et la protection des écosystèmes du territoire dans le but de protéger les espèces menacées et d'assurer principalement la perpétuation des activités traditionnelles des Autochtones et, en second lieu, la satisfaction des besoins des non-Autochtones en matière de chasse et de pêche sportives.

Elle exige aussi des gouvernements responsables qu'ils portent une attention particulière à des principes directeurs bien définis comme la protection des ressources fauniques, du milieu physique et biologique et des écosystèmes de la région relativement aux activités de développement touchant la région. Ils doivent voir également à la réduction, par des moyens raisonnables et plus

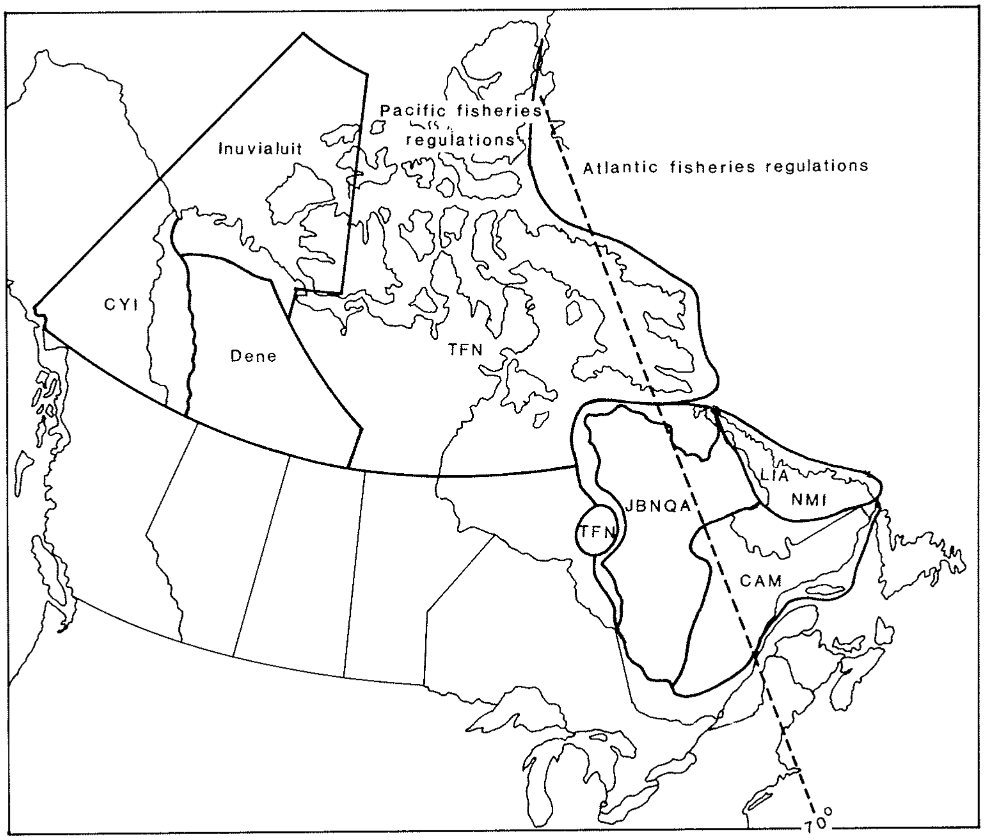

Figure 17. Cadre politique s'appliquant a l'Arctique canadien.

particulièrement par les mesures proposées, recommandées ou établies à la suite du processus d'évaluation et d'examen, des répercussions indésirables découlant du développement et relatives à l'environnement et au milieu social des Autochtones et non-Autochtones et des communautés autochtones et non autochtones. Le contexte politique crée donc des obligations au niveau scientifique notamment en ce qui concerne l'étude et le suivi des populations et de leur écosystème (Tableau 8).

Bien que ces obligations s'appliquent à tout le territoire, les besoins spécifiques seront identifiés selon l'état des ressources à protéger ou à utiliser dans le cadre d'une exploitation soutenue ou selon l'apparition de problèmes à caractère environnemental.

JURIDICTIONS

La délégation du gouvernement fédéral au gouvernement provincial de l'administration de la pêche des poissons d'eau douce (1922) et des espèces anadromes et catadromes dans les eaux à marée décrites au Règlement de pêche du Québec (1983) établit un partage des responsabilités scientifiques pour ces espèces. D'une manière générale, dans le sud de la province, et en pratique,

Table 8. Domaines de recherche découlant du contexte politique.

OBLIGATIONS: CBJNQ	DOMAINE SCIENTIFIQUE CONCERNÉ
"Principe de conservation" (ch.24) (protéger, maintenir, développer)	. dynamique et suivi de populations
"Suivi des principes directeurs" sur l'environnement (ch.23)	. étude du milieu physique . étude du milieu biologique . étude des écosystèmes . évaluation d'impact

dans le Nord, le ministère du Loisir, de la Chasse et de la Pêche réalise des programmes de recherche sur les espèces d'eau douce, anadromes et catadromes. Par contre, le Fédéral demeure responsable de la recherche en milieux hauturiers, à partir de la limite des basses eaux, ainsi que dans les eaux à marée de certaines régions non couvertes par le Règlement de pêche du Québec, soit celles du Nouveau-Québec (Tableau 9).

Table 9. Contexte fédéral et provincial.

RÈGLEMENT	APPLICATION	NOTE
Règlement de pêche des TNO	Toutes les eaux des TNO	TNO=Nord du 60^{o} donc ne touche pas aux baies d'Hudson et James
Règlement de pêche de l'Atlantique	Eaux à marée du Nord québécois Eaux de la baie d'Ungava Eaux du détroit d'Hudson à l'est du 70^{o}00' de longitude ouest	N'implique pas l'omble chevalier; inclut le saumon
Règlement de pêche du Québec	Dans la province Dans les eaux à marée décrites en annexe	Province=limite des basses eaux Eaux à marée décrites pour le sud de la province seulement

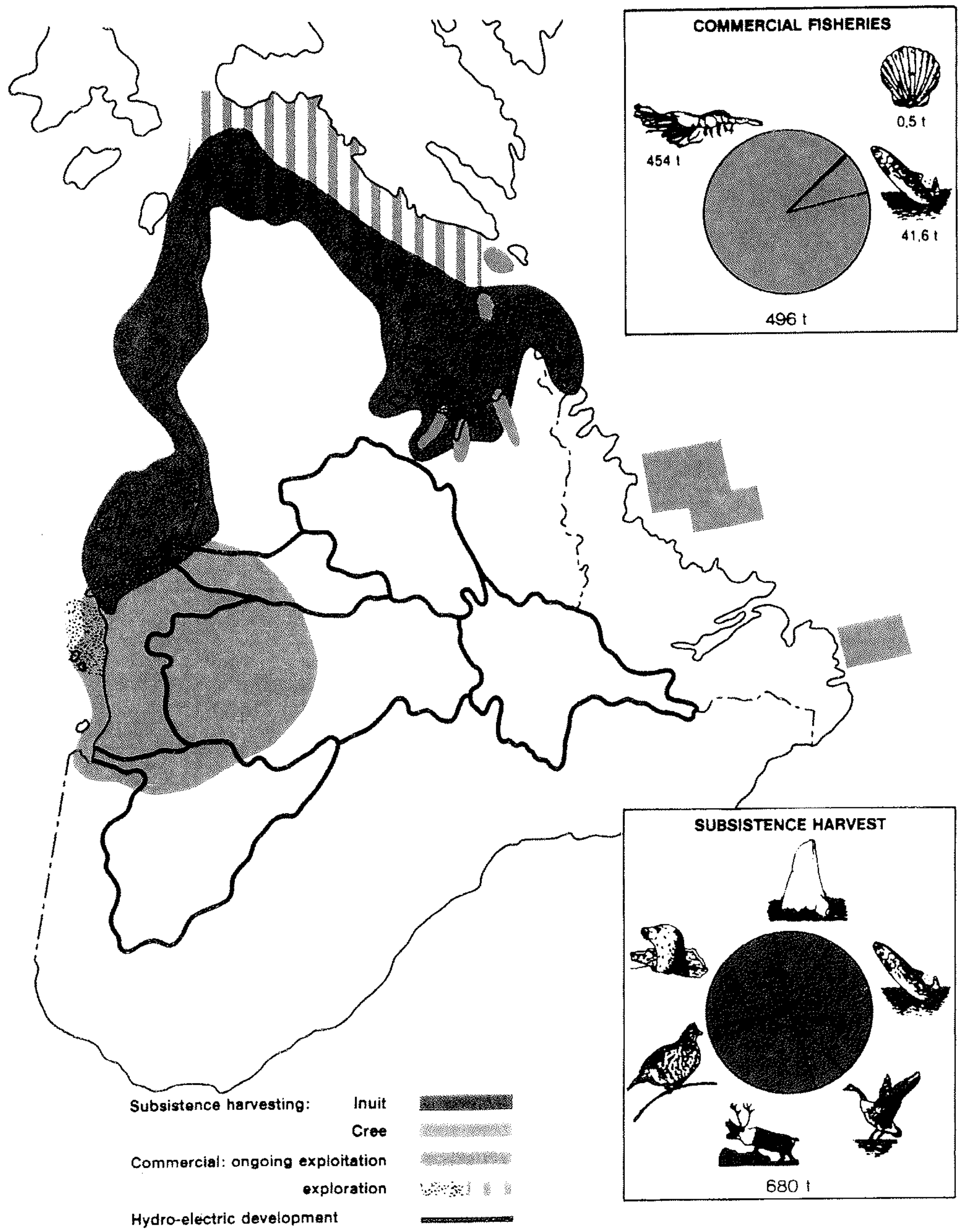

Figure 18. Utilisation des ressources du Québec nordique.

EXPLOITATION COURANTE ET GESTION DES RESSOURCES MARINES
SUBSISTANCE

L'ensemble des espèces marines et anadromes distribuées dans les zones côtières est exploité aux fins de subsistance (Fig. 18). Mammifères marins et poissons anadromes forment un fort pourcentage des récoltes totales et des récoltes des communautés du détroit d'Hudson. En termes de gestion, deux espèces sont présentement visées, soit le béluga et le morse. Le béluga constitue nettement une priorité puisque deux populations estivales du Nord québécois, celle de la baie d'Ungava et celle de l'est de la baie d'Hudson, sont

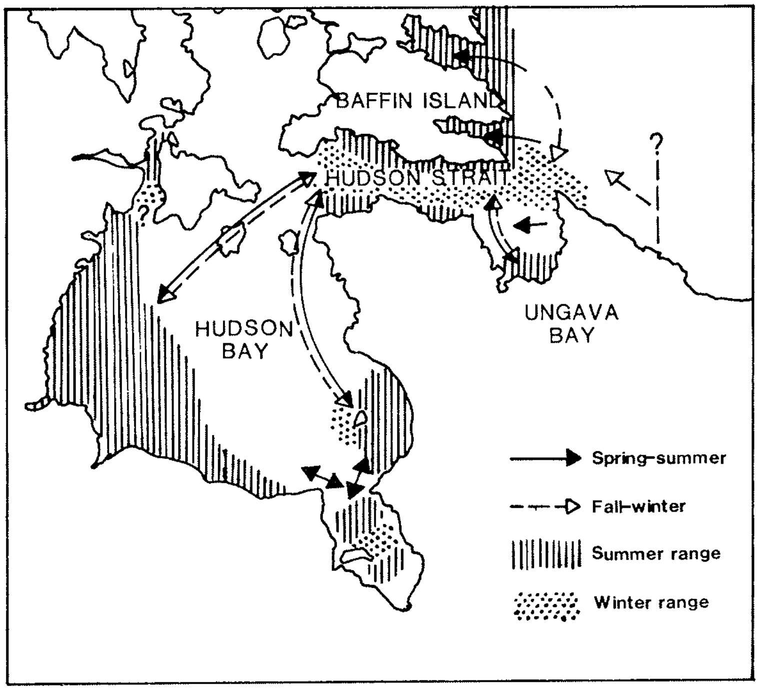

Figure 19. Distribution saisonnière et patrons de migration des populations de bélugas de l'est de l'Arctique.

respectivement considérées comme menacées et en danger (Fig. 19). Une troisième population estivale de l'est de l'Arctique, celle du détroit de Cumberland, est aussi menacée.

L'état de ces populations oblige donc le ministère des Pêches et des Océans à prendre les mesures nécessaires pour assurer leur conservation. Depuis 1983, une approche de co-gestion est donc élaborée entre le Ministère, les représentants inuit et les chasseurs . Des mesures ont ainsi été identifiées: des contingents ont été établis, un sanctuaire créé, et des règles de chasse définies sur la base des données scientifiques disponibles. La méconnaissance de l'identité des populations constitue la principale limite à l'amélioration de ces mesures.

Le morse de l'est de l'Arctique, pour sa part, n'est classé, par COSEWIC, dans aucune catégorie. La connaissance de ces stocks demeure limitée et, par conséquent, notre base de gestion l'est également (Fig. 20).

COMMERCE

L'exploitation commerciale, jusqu'au début des année 1980, portait principalement sur les espèces anadromes, le saumon étant celle qui est exploitée depuis le plus longtemps (Tableau 10). Depuis 1980, avec le développement de la filiale Seaku de Makivik et des efforts de développement des pêches investis par le MPO,

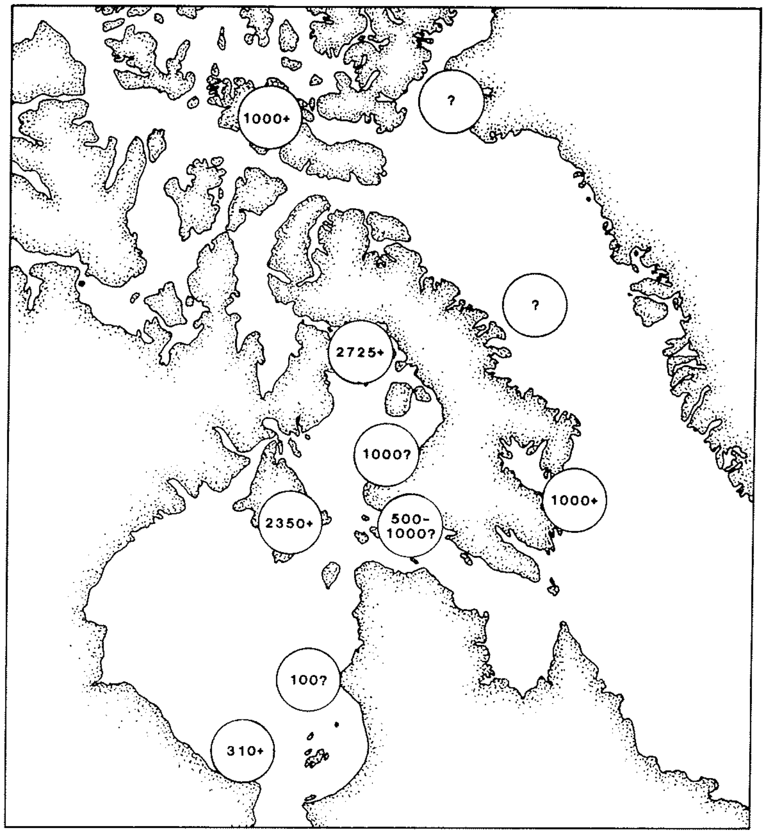

Figure 20. Localisation et estimation des divers stocks de morse répertoriés.

le MAPAQ et le MAIN, les espèces marines font l'objet d'une pêche commerciale ou d'exploration (Fig. 18). L'espèce qui domine par ses prises est la crevette suivie du pétoncle (Tableau 11). Le détroit d'Hudson, et particulièrement le secteur "est", supporte le plus grand effort de pêche commerciale d'espèces marines. Le Tableau 12 et la figure 21 résument la situation actuelle relativement aux activités commerciales reliées à la pêche.

DÉVELOPPEMENT DES PÊCHES

Depuis 1984, par ailleurs, divers programmes spéciaux ont été mis de l'avant pour développer les pêches du Nord québécois ainsi que celles des Territoires du Nord-Ouest. Nommons le programme de développement des pêches du Nord québécois du MPO (5 millions $), l'Entente auxiliaire Canada-Québec sur le développement des pêches (2 millions $), le Programme de développement des pêches de l'Atlantique et le Programme Essai et Expérimentation (1 million $) dont un volet

Table 10. Principales initiatives passées de commercialisation des pêches au Nouveau-Québec.

A: Initiatives lancées par la compagnie de la Baie d'Hudson en vue de l'exploitation à grande échelle du béluga, du saumon (1967 et 1939) et de l'omble chevalier:

De 1854 à 1869:
- dans la Grande rivière de la Baleine
- dans la Petite rivière de la Baleine
- dans le lac Guillaume Delisle

De 1890 à 1904:
- dans la Rivière George
- dans la Rivière aux Feuilles
- dans la Rivière à la Baleine

De 1830 à 1842, 1867 à 1904:
- dans la Rivière Koksoak

B: Activités de pêche lancées par le ministère des Affaires indiennes et du Nord et par le ministère de la Chasse et de la Pêche du Québec:

De 1961 à 1969 – saumon:
- dans la Rivière Koksoak (Kuujjuaq)
- dans la Rivière à la Baleine

De 1959 à 1967 – omble chevalier:
- dans la Rivière George (Kangiqsualujjuaq)
- de Kangiqsualujjuaq au fjord Allurilik
- à Tasiujaq
- dans la Rivière Arnaud (Kangiqsuk)
- dans la Rivière à la Baleine
- dans la Rivière Koksoak (Kuujjuaq)
- dans la lac Guillaume Delisle

vise le Nord québécois. Adaptés aux orientations régionales de développement et aux priorités des divers groupes autochtones concernés, ces programmes injectent des fonds spéciaux dans divers types de projets dont certains visent à accroître nos connaissances scientifiques (Tableau 11).

GESTION DE L'HABITAT DU POISSON

Cette division du Ministère intervient au niveau de l'application de la loi sur les pêcheries et dans la mise en oeuvre de la politique sur l'habitat du poisson et de l'objectif "pas de perte nette mais gains nets". Les actions sont donc orientées selon le cas au niveau de la conservation, de la restauration et des évaluations d'impact.

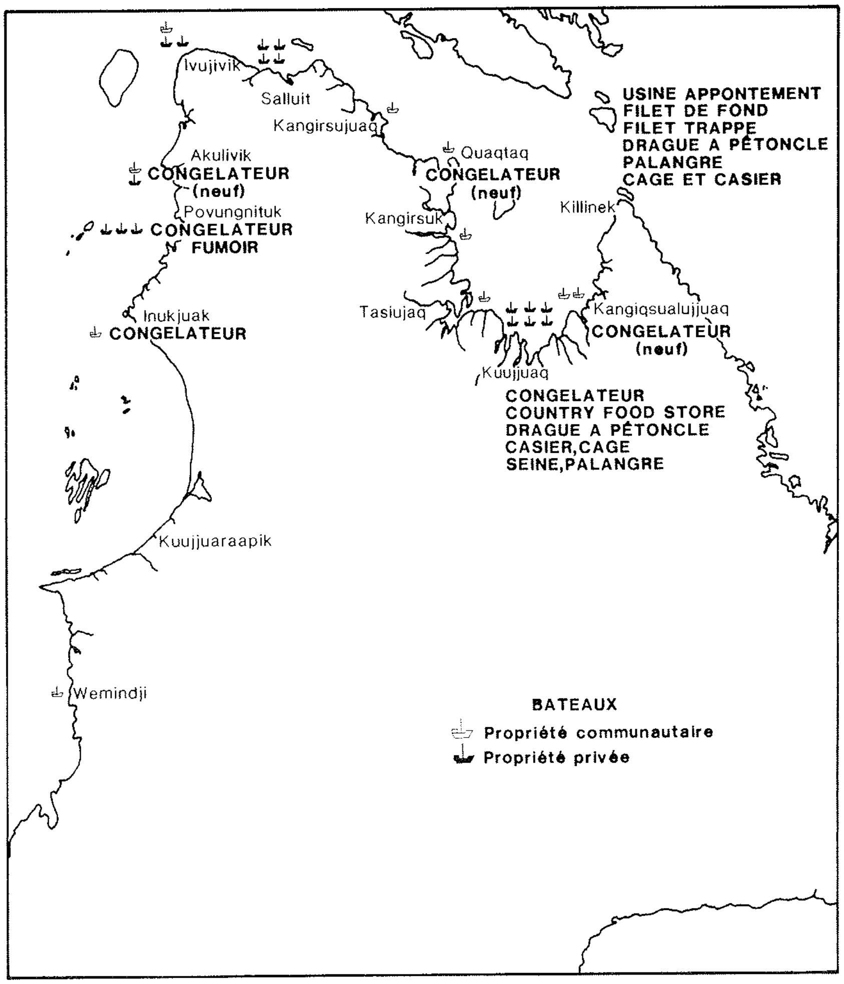

Figure 21. Carte inventaire des équipements et infrastructures de pêche.

Au Nord québécois, la mise en oeuvre des chapitres 22 et 23 de la CBJNQ et le suivi environnemental des projets de développement hydro-électrique constituent la principale activité de la Division de l'habitat du poisson. A court terme, le projet Grande-Baleine est celui qui retiendra l'attention. A long terme, on peut inclure la problématique du transport à longue portée des contaminants et la mise en oeuvre de la Stratégie canadienne de conservation du milieu marin arctique.

Table 11. Initiatives récentes de commercialisation des pêches au Nouveau-Québec.

De 1960 à 1984:	Exploitation sporadique de la morue à Killiniq
À compter de 1961:	Exploitation du saumon et de l'omble chevalier par la coopérative Kuujjuaq et, plus tard, celle de Kangiqsualujjuaq et aussi par des promoteurs individuels
De 1979 à 1981:	Pêche exploratoire de la crevette nordique par la Société Makivik (Imaqpik)
À compter de 1986:	Reprise de la pêche commerciale à la crevette nordique par la Société Makivik (Seaku Fisheries inc.)
De 1982 à 1985:	Fumage de l'omble chevalier à Povungnituk
Depuis 1987:	Pêche exploratoire du pétoncle dans l'Ungava et le détroit d'Hudson (J.Peters/Makivik)
Depuis 1988:	Pêche commerciale d'hiver à l'omble chevalier à Kangiqsualujjuaq (Annanak & Sons)

Table 12. Projets réalisés dans le cadre de l'entente auxiliaire Canada-Québec sur le développement des pêches: volet III: Québec nordique.

PROJETS		$	CONTENU SCIENTIFIQUE
1987-1988			
101	Plan Cri-Naskapi	21 000	
102	Étude congélateur	8 071	
103	Annanack	32 500	Suivi biologique omble chevalier
1988-1989			
201	Corégone et esturgeon	110 000	Dynamique et évaluation de population, parasitologie
202	Camion réfrigéré	50 000	
203	Schefferville	43 814	
205	Wemindji	150 000	Pêche exploratoire pour espèces marines
207	Pétoncle recherche	28 000	Caractérisation des stocks
208	Recherche crevette	42 300	Caractérisation des stocks
209	Saumon Whale	24 000	Suivi biologique
210	Omble chevalier	94 400	Barrière de comptage: évaluation de stocks
211	Omble aménagement	4 845	
212	Plan eau douce	4 280	
213	Récolte morse	25 000	Paramètres biologiques, trichinose
214	Congélateur Kangiqsualu	50 000	
215	Congélateur Quaqtaq	50 000	
216	Congélateur Akulivik	50 000	
218	Réparation bateau	7 000	
220	Transfert technologique	40 000	
221	Frais de coordination	4 877	
	Frais administ. MAS	6 498	

Table 12. *Continued.*

	PROJETS	$	CONTENU SCIENTIFIQUE
1989-1990			
301	P. Haut. d'Hudson	90 000	Exploration crevette, poisson de fond
302	Réparation bateau	35 000	
304	Marketing	40 000	
305	Transf. technol. phase 2	50 000	
306	Sappukait	40 000	Barrière de comptage (suivi) omble chevalier
307	Annanack	15 000	Suivi biologique omble chevalier
308	Équipement Kangiqsualu.	7 500	
309	Agent de développement	50 000	
310	Exploration en eau douce	50 000	Biologie des espèces eaux douces
311	Projets de pêche	50 000	Évaluation stocks omble chevalier
312	Aménagement omble chev.	20 000	
313	Bateau Saluit	13 500	
314	Pisciculture Schefferv.	130 000	
315	Corégone	220 000	Dynamique de population, évaluation de stocks, parasitologie
	Frais administ. MAS	10 000	

Table 12. *Continued.*

	PROJETS	$	CONTENU SCIENTIFIQUE
1990-1991			
401	Pêche expérimentale Kangiqsualujjuaq	65 012	Étude de l'omble chevalier
402	Pêcherie commerciale Baie d'Hudson	75 000	Évaluation du potentiel de pêche à l'omble chevalier
403	Pêcherie commerciale Kangiqsualujjuaq	5 000	Suivi d'une pêche d'hiver à l'omble chevalier
404	Assistance au pêcheur Assivaq	4 575	
405	Intérêt sur achat bateau	4 542	
406	Pêches commerciales Québec nordique	34 050	Programme de développement
407	Rénovation du fumoir Povungnituk	39 000	
408	Synthèse de la recherche Baie d'Ungava	8 010	Recherche effectée sur l'omble chevalier
409	Développement pour l'entreprise Inuksiutiit	7 500	
410	Salmonidés, Québec nordiques	40 095	Étude de pré-faisabilité d'élevage
411	Rénovation du congélateur Povungnituk	20 800	
412	Pêche commerciale au Québec nordique	15 924	Encadrement et suivi des activités
413	Pêche commerciale Waswanipi-Baie James	218 500	Développement d'une pêche en eau douce
414	Aquaculture à Schefferville/Kawachikamach	135 900	

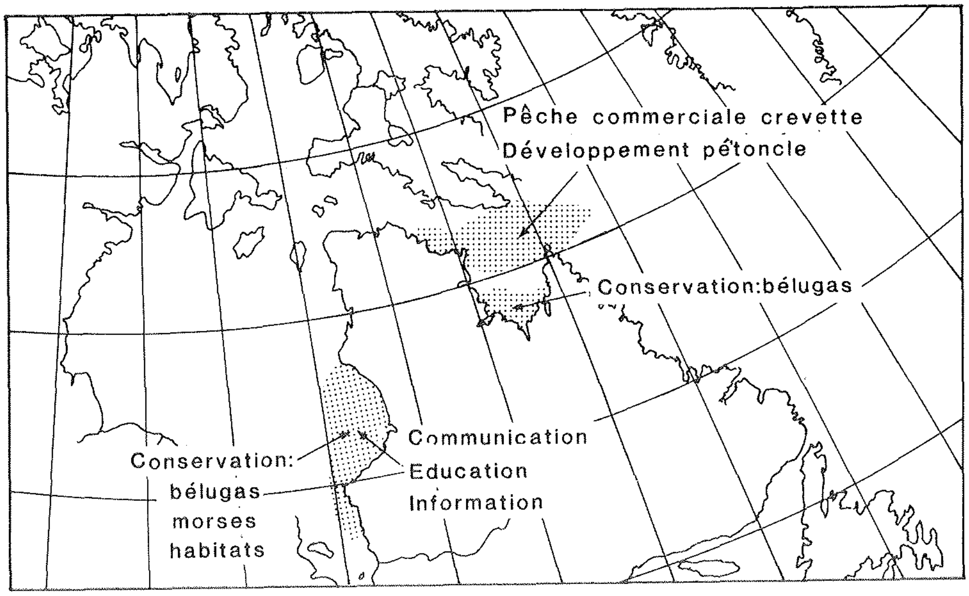

Figure 22. Priorités de gestion des pêches et de l'habitat du poisson ayant une incidence sur la recherche.

CONCLUSION

La Figure 22 illustre les régions et les sujets prioritaires pour la Direction de la gestion des pêches et de l'habitat du poisson. Ainsi, l'est de la baie d'Hudson est une région prioritaire pour la conservation des bélugas, des morses et la protection des habitats côtiers; le détroit d'Hudson, particulièrement le secteur "est", est prioritaire pour l'exploitation commerciale et pour le développement des pêches, surtout de la crevette, du pétoncle et des poissons de fond. L'ouest du détroit d'Hudson est visé relativement à la conservation des morses. Finalement, le sud de la baie d'Ungava est prioritaire pour la conservation des bélugas. Ces priorités de conservation et de gestion exigent un support scientifique au niveau de la connaissance des écosystèmes, et du milieu physique et biologique, pour l'évaluation et le suivi des populations, leur caractérisation et la compréhension de leur dynamique et des interactions à l'intérieur de la chaîne alimentaire.

ABSTRACT OF PAPERS PRESENTED

AT HUDSON STRAIT WORKSHOP

NOVEMBER 9, 1989

ON THE SEASONALITY OF THE OUTFLOW IN HUDSON STRAIT

K.F. Drinkwater

Department of Fisheries and Oceans
Physical and Chemical Sciences Branch
Bedford Institute of Oceanography
Box 1006, Dartmouth, Nova Scotia, B2Y 4A2

Initial results from a pressure and current meter array in Hudson Strait from October 1986 to August 1987 are presented. Five current meters and 3 subsurface pressure gauges were deployed along the Quebec coast near Wales Island (just north of Wakeham Bay) to monitor the seasonality of the low salinity, seaward moving coastal current. The monthly mean residual current near surface (40 m) shows a maximum along channel speed in October of 0.6 m s^{-1} and a relatively constant flow of 0.2 m s^{-1} during the late winter and early spring (February to June). High variability at periods of 5-10 d is evident through the 11-month record. The salinity minimum near surface occurred in December and is believed to be associated with the peak runoff into Hudson Bay in summer.

PLANS FOR PHYSICAL OCEANOGRAPHIC RESEARCH AT THE HUDSON BAY - HUDSON STRAIT - FOXE BASIN JUNCTION

P. Larouche

Department of Fisheries and Oceans
Maurice Lamontagne Institute
850, Route de la Mer, C.P. 1000
Mont Joli, Québec, G5H 3Z4

Hudson Strait can be divided into three main ecosystems: eastern and western entrances and the central part. Both ends of the Strait are known areas of productivity and strong mixing and are thus good candidates for an integrated subarctic ecosystem study. A brief review of another ecosystem study results - the St. Lawrence estuary- will be given in order to see what can be learned from past experience.

Then a proposal will be made to study the western part of Hudson Strait over the next few years. The junction between Hudson Strait, Hudson Bay and Foxe Basin is oceanographically very complex. It is an area where intense mixing takes place between three major water masses having different characteristics: Atlantic, Arctic and Hudson Bay. A good basic study of the physics of this region of confluence would take three years. The first phase of this project will gather salinity, temperature and much needed current and water level data over the global area in order to get a general picture of the physical oceanographic processes taking place. Biological and chemistry measurements should also be made to complement these measurements. The study should look at exchanges between a particular water body and the rest of the system by installing current meters for year-long deployments. A specific station would always be monitored over the course of this project in order to relate the three data sets.

Use of a large ship for one month would be required for a preliminary survey of the area. This could be completed using local cruises from a nearby field station. Winter surveys from fast ice or drifting ice floes would be important to both physical and biological research. Extensive use of remote sensing would also help monitor the global Hudson Strait system.

CARBON FLUX IN ARCTIC MARINE SYSTEMS

J.N. Bunch

Department of Fisheries and Oceans
Arctic Biological Station
555, boul. St-Pierre
Ste-Anne-de-Bellevue, Québec, H9X 3R4

A review of carbon flux as a measure of biological productivity of an arctic marine system can reasonably begin with a description of organic carbon production at the ice-water interface during the arctic spring. Although no ice data are available from the area of Hudson Strait, studies in the nearby waters of Frobisher Bay have demonstrated considerable production of organic carbon by a community of organisms in the bottom of spring ice. Levels of particulate organic carbon as high as 192 mg m^{-2} in the bottom 5 cm of the ice column were observed compared to concentrations about 12 times less (on a litre basis) in the underlying water. Concurrently, concentrations of dissolved organic carbon at 240 mg m^{-2} exceeded usual concentrations in the water column by a factor of 4 (on a litre basis). In this community, the standing stock of bacteria increased by five fold while their rate of production increased from zero to $6x10^9$ cells m^2 day^{-1} (approximately 1.0 mg of carbon) thereby suggesting predation of the assemblage of bacteria by larger organisms during this time. Prior to the decay of the sea ice and release of the community into the water column, bacteria constituted as much as 5% of the standing stock of particulate organic carbon in the bottom of the ice.

Release of the ice community into the water column during breakup of the sea ice has been observed in earlier studies and it is soon followed by the summer bloom of phytoplankton. Levels of chlorophyll are closely correlated to those of particulate organic carbon and a subsequent increase in dissolved organic carbon occurs. During this time, the standing stock of bacteria increases by about an order of magnitude despite probable predation.

In an abbreviated sampling of Sugluk and Wakeham Bays on the north shore of Quebec adjacent to Hudson Strait in 1989, preliminary data include chlorophyll and standing stock of bacteria but measurements of particulate and dissolved organic carbon are currently under review. Wakeham Bay has larger tides and in 1989, a more saline environment than Sugluk Bay. Using Frobisher Bay as a model, it appears that Sugluk Bay had an earlier bloom of phytoplankton and bacteria and, at least in the case of bacteria, a peak of cell concentration about two times less than in Wakeham Bay where the bacterial bloom was apparently ongoing. On limited data, it is possible that at least in 1989, Wakeham was more productive than Sugluk Bay.

ICE ALGAE PRODUCTION NEAR CHESTERFIELD INLET, NORTHWEST COAST OF HUDSON BAY

H.E. Welch, M. Bergmann and T. Siferd

Department of Fisheries and Oceans
Freshwater Institute
501 University Crescent
Winnipeg, Manitoba, R3T 2N6

Ice algae biomass increased exponentially from February to late April 1988, reaching chlorophyll levels of 200 mg m^{-2} over deep (>100 m) water, but only 20 mg m^{-2} over shallow (<40 m) water beneath low snow. Doubling times were 10 d and 22 d respectively. Under variable snow cover, chlorophyll distribution was predictable as a log function of overlaying snow depth, again with much higher algal biomass over deep water than over shallow. Phosphate and silica were similar at all sites sampled, whereas nitrate was always low over shallow water and relatively high over deep water. Despite very abundant ice-associated amphipods over shallow and mid-water depths (means of a few hundreds per square meter), there was little evidence that grazing by amphipods was limiting ice algal growth over shallow water. We postulate that benthic macroalgae, which are abundant in Hudson Bay coastal waters, remove nitrate in midwinter before sufficient light for ice algal growth occurs. This in turn limits the growth of ice algae over shallow water, but over deep water there is sufficient nitrate and vertical mixing to allow high biomass development. If this is correct, the near-shore Hudson Bay environment (approximately coinciding with shore-fast ice) should have relatively low ice algal and phytoplankton production relative to deeper offshore waters.

Comparing these results with recent work near Resolute in Barrow Strait (75°N lat.), we find that ice algal biomass at both locations is a predictable function of overlying snow depth and cumulative surface radiation, provided nitrate is not limiting. A simple model relating cumulative light and snow depth is a good estimator of ice algal biomass. Because Hudson Strait is deep, probably well-mixed in late winter, and probably has high surface nitrate concentrations before the beginning of the spring phytoplankton bloom, we expect that the same model will be a good estimator for Hudson Strait ice algal development.

COUPLING BETWEEN ICE-ALGAL PRODUCTIVITY AND THE PELAGIC FOOD WEB IN SOUTHEASTERN HUDSON BAY

J.A. Runge

Department of Fisheries and Oceans
Maurice Lamontagne Institute
850, Route de la Mer, C.P. 1000
Mont Joli, Québec, G5H 3Z4

In southeastern Hudson Bay, a bloom of ice microalgae occurs at the ice-water interface in April-May. Females of the biomass-dominant copepod species, *Calanus glacialis* and *Pseudocalanus* spp., migrate to the interface at night to feed. Two numerically abundant species, *Oithona similis* and *Acartia longiremis* are also found near the underice surface day and night, but *Oncea borealis* and *Microcalanus pygmaeus*, the other common copepod species, do not concentrate at the interface. While grazing by planktonic copepods takes place during the ice-algal bloom, a significant increase in zooplankton production (as measured by egg production rates) occurs principally after release of ice algal cells and during their subsequent suspension in the water column during the period of ice break-up. Larvae of arctic cod and sand lance also appear immediately after ice-algal release, suggesting a link with the ice-algal enhanced zooplankton productivity. It is not clear to what extent the trophic coupling between zooplankton and ice algae in southeastern Hudson Bay pertains to other regions in the Canadian Arctic.

REVIEW OF ZOOPLANKTON AND THE ICE FAUNA

E.H. Grainger

Department of Fisheries and Oceans
Arctic Biological Station
555 boul. St-Pierre
Ste-Anne-de-Bellevue, Québec, H9X 3R4

Little work on zooplankton and none on the sea ice fauna has been carried out to date in Hudson Strait, as defined in its narrowest geographical sense. We must, therefore, draw on information from adjacent waters in order to construct a provisional working model of zooplanktonic and ice faunal relationships in the Strait. Available data indicate the presence (excluding the Protista) of about 150 species of zooplankton, not counting the meroplankton. The major oceanographic influence appears to be subarctic, with entry of indicator plankters in subsurface Atlantic water from the east, and a gradual decrease in their numbers towards the west. Extreme seasonal variation in biomass is to be expected, with summer levels exceeding those of winter by from one to two orders of magnitude, numbers mainly governed by food supply and predation. Growth and development are largely restricted to the open-water period of summer, with year-long or longer life cycles characterizing at least the herbivorous zooplankton. In nearby waters, copepods were shown to have the highest caloric content among the major zooplanktonic groups studied. Ctenophores and coelenterates had the lowest content, and amphipods, chaetognaths and some other groups had intermediate levels. The principal zooplanktonic herbivores in Hudson Strait appear to include *Calanus*, *Pseudocalanus*, *Oithona* and *Metridia* (copepods), *Spiratella* (pteropod) and polychaete larvae, the major carnivores *Themisto* (amphipod) and *Sagitta* (chaetognath).

In winter, a special fauna comprising some 20 to 40 species having strong benthic affinities has been found living in the sea ice in waters adjacent to Hudson Strait. This fauna is most concentrated in the lower 5 cm of the ice sheet. It is dominated by nematodes, polychaete larvae, cyclopoid and harpacticoid copepods. Concentrations in the ice run some 4 orders of magnitude higher than those found in the plankton under the ice at the same time of year, and some 3 orders higher than in the water at the height of the summer season.

Studies on the ice biota have not been carried out in Hudson Strait. It is reasonable to suppose, nevertheless, that the ice fauna will be found to be as important in the Strait as it appears to be in other regions with a sustained winter ice cover. Concentrated and readily available animal biomass is present in the ice at a time when plankton concentrations are especially low in the water below. Trophic links between the ice fauna and such under-ice predators as amphipods and copepods have been identified, and these may be extended to include, for example, the arctic cod and ringed seal. Zooplankton biomass develops following the disappearance of the ice and its fauna. Additional feeding links relate dominant zooplankters (copepods, amphipods, chaetognaths and others) to a variety of fishes, birds and mammals through the remainder of the open-water season.

THE DISTRIBUTION AND BIOMASS OF MACROZOOPLANKTON IN EASTERN HUDSON STRAIT WITH EMPHASIS ON HYPERIID AMPHIPODS OF THE GENUS *THEMISTO*

J.A. Percy

Department of Fisheries and Oceans
Arctic Biological Station
555 boul. St-Pierre
Ste-Anne-de-Bellevue, Québec, H9X 3R4

Three species of pelagic amphipods of the genus *Themisto* are widely distributed in arctic, subarctic and north temperate waters of the north Atlantic. Their importance and ecological role in these cold northern waters has been likened to that of the krill in the Antarctic in that they often occur in large swarms and form an important food for a variety of marine fish, birds and mammals. All three species, *T. libellula, T. compressa* and *T. abyssorum*, were collected in the waters of eastern Hudson Strait during two summers of sampling. The horizontal and vertical distributions of the three species in the area differed considerably and appeared to be related to the interaction of Atlantic and arctic water masses within the Strait. *T. compressa* was largely restricted to the eastern entrance of the Strait, particularly in the vicinity of Resolution Island. T. Libellula is more prevalent within the Strait itself and around Resolution Island appears to occur primarily in near surface waters. *T. compressa* has a much broader depth distribution in this area. *T. abyssorum* was much less abundant than the other two species, but was found throughout the area, usually at depths below 100 m. In terms of numbers of individuals collected during 1987, *T. libellula* was by far the dominant species (68%), followed by *T. compressa* (29%) and distantly by *T. abyssorum* (3%). Only a single size cohort was evident in the size frequency distributions of all three species, with modes at 12.0, 11.2 and 6.0 mm for *T. libellula, T. compressa* and *T. abyssorum*, respectively. The distribution and biomass of the other principal macrozooplankton species occurring in the area are also briefly discussed.

HYDROACOUSTIC OBSERVATIONS OF THE VERTICAL DISTRIBUTION OF MACROZOOPLANKTON IN EASTERN HUDSON STRAIT

R. Crawford

Department of Fisheries and Oceans
Freshwater Institute
501 University Crescent
Winnipeg, Manitoba, R3T 2N6

Fisheries acoustics was used in conjunction with the BIONESS plankton sampler and a Sputnik shrimp trawl to examine the vertical distribution of shrimp (*Pandalus montagui*) and macrozooplankton biomass in eastern Hudson Strait. During one portion of the survey, echo integration and the BIONESS were used simultaneously at two hour intervals to determine the distribution of biomass in the water column. BIONESS samples were used to ground truth the hydroacoustic data and to examine the composition of the zooplankton community. During another portion of the survey, a commercial-type shrimp trawl was used to sample near the bottom in areas where biomass concentrations were detected acoustically.

Examination of the acoustic data revealed a strong diel component in the distribution of shrimp. Large, relatively sparse concentrations of shrimp were contagiously distributed throughout the water column during nighttime. Shrimp distribution was patchy enough to generate variability in the catches of the BIONESS sampler during this time. During daylight hours, shrimp biomass was often concentrated near the bottom, a region sometimes ineffectively sampled by the BIONESS. The near-bottom depth stratum was effectively sampled by the shrimp trawl but sometimes shrimp biomass was distributed well above that depth layer.

Our findings indicate that shrimp and macrozooplankton biomass distribution in eastern Hudson Strait is extremely dynamic. This characteristic will influence the between-sample variability of catches by a plankton sampling device such as the BIONESS. Extrapolation of plankton samples into descriptors of community structure and dynamics is greatly enhanced by the simultaneous collection of acoustic data. Furthermore, shrimp and macrozooplankton biomass is occasionally concentrated in an area that is not well sampled by either the BIONESS or the bottom trawl: too high off the bottom for the trawl and yet too close to the bottom for the BIONESS. Our acoustic data filled the void in the sampling capabilities of the other two gears. We conclude that total water column studies of the shrimp and macrozooplankton communities in this area are best executed with a combination of fisheries acoustics, a bottom trawl and a plankton sampler.

LARVAL FISH, ZOOPLANKTON COMMUNITY STRUCTURE, AND PHYSICAL DYNAMICS AT A TIDAL FRONT

C.T. Taggart[1], K.F. Drinkwater[2], K.T. Frank[2], J. McRuer[2] and P. Larouche[3]

[1] Dalhousie University, Department of Oceanography
Halifax, Nova Scotia, B3H 4J1

[2] Department of Fisheries and Oceans
Bedford Institute of Oceanography
Dartmouth, Nova Scotia, B2Y 4A2

[3] Department of Fisheries and Oceans
Maurice Lamontagne Institute
Mont Joli, Québec, G5H 3Z4

Physical, chemical, and biological measurements at the Akpatok Shallows, Ungava Bay, Québec, in September 1985 confirmed the existence of a front predicted earlier from the Simpson-Hunter h/u^3 stratification parameter. Temperature, salinity, and nutrient data indicated a combination of tidal advection, upwelling and mixing at the front. Nitrate concentrations of ≈ 5 ug-at 1^{-1} were found in the deeper stratified water near the front. Chlorophyll a concentrations of ≈ 4 ug 1^{-1} occurred on the stratified side of the front. The macrozooplankton community was horizontally delineated by the extent of vertical stratification. Jellyfish, *Limacina* spp. and *Clione* spp. were concentrated at the front in contrast to amphipods, mysids, and euphausiids that were concentrated in the stratified water, and decapod larvae in the mixed water. Chaetognaths and larval fish showed similar distributions on either side of the front, but were rare at the front. The spatial distributions of the major larval fish taxa were either consistent with (Cottidae) or contrary to (Cyclopteridae) the retention hypothesis. Distributions of cyclopterid and gadoid larval sizes illustrated enhanced survival and/or growth on the stratified side of the front.

SPATIAL AND TEMPORAL VARIABILITY OF MACROINVERTEBRATE ASSEMBLAGES

C. Hudon

Department of Fisheries and Oceans
Arctic Biological Station
555 boul. St-Pierre
Ste-Anne-de-Bellevue, Québec, H9X 3R4

The three macroinvertebrate assemblages characteristic of the offshore, coastal and nearshore areas of Hudson Strait and Ungava Bay are described. Each assemblage includes at least one species of interest for human consumption. The nearshore community (intertidal to 10 m) is not very diversified, and is dominated by the blue mussel (*Mytilus edulis*). The diversity and abundance of this community may be controlled by winter conditions, especially ice scouring in the intertidal zone. The community found in the coastal area (30-100 m) has a very diversified fauna, including the Iceland scallop (*Chlamys islandica*).

Although the species richness of this community has been described qualitatively, little is known of the factors determining its structure. The deepwater areas offshore at the eastern end of the Strait (> 300 m) are characterized by pandalid shrimps (*Pandalus montagui* and *P. borealis*). However, little is known of the distribution and abundance of demersal macroinvertebrates other than those captured in shrimp trawls. Pandalid shrimp abundance and distribution in those areas are influenced by circulation and mixing between arctic and Labrador Sea waters.

REVUE DES CONNAISSANCES ET DES TRAVAUX EN COURS SUR L'OMBLE CHEVALIER ANADROME (*Salvelinus alpinus*) DU NORD QUÉBÉCOIS

L. Roy[1], T. Boivin[2], S. Olpinski[2],
R. Dumas[2], F. Axelsen[3] et D. Gillis[4]

[1] Ministère du Loisir, de la Chasse et de la Pêche
Direction régionale du Nouveau-Québec
1995, boul, Charest ouest
Ste-Foy, Québec, G1N 4H9
[2] Société Makivik, Centre de recherche de Kuujjuaq, J0M 1C0
[3] Ministère de l'Agriculture, des Pêcheries et de l'Alimentation, Service de la recherche
1665, boul. Wilfrid Hamel ouest, Édifice 2
Québec, G1N 3Y7
[4] Department of Fisheries and Oceans
Box 2000, Charlottetown, Prince Edward Island, C1A 7N8

L'omble chevalier anadrome du Nord québécois est principalement exploité à des fins d'alimentation par les Inuit, mais également par la pêche sportive et la pêche commerciale. Nous observons actuellement un accroissement important de la demande pour les trois (3) modes d'exploitation et nous prévoyons que cette tendance devrait se maintenir. Règle générale, les stocks éloignés des communautés sont sous-exploités alors que les stocks rapprochés sont virtuellement surexploités. Dans ce contexte, le bilan des connaissances sur l'Omble chevalier et l'orientation des travaux en cours ou futurs s'inscrivent dans l'objectif global de la mise en valeur de la ressource, en assurant la conservation des stocks reproducteurs et la détermination des niveaux d'exploitation biologiquement acceptables. A cette fin, l'approche que nous prévilégions est le concept d'aménagement par stock à partir des données sur le segment exploitable des populations. La pêche côtière en mer implique à cet égard des difficultés majeures de gestion.

Parmi les informations disponibles, les connaissances des Inuit sur la ressource sont d'une grande utilité, en particulier pour l'identification et le statut des systèmes producteurs, l'écologie des migrations et de la population. Les données quantitatives proviennent d'études sur l'exploitation et la biologie de l'Omble chevalier. Un bon nombre de données disponibles sur la pêche d'alimentation proviennent d'études globales sur les niveaux de capture par communauté qui sont difficilement utilisables dans l'évaluation des stocks.

D'autres études plus sectorielles et ponctuelles établissent le nombre de prises par système. Une recherche dans les données d'archives de la pêche commerciale (antérieures à 1960) laisse peu d'espoir sur l'utilisation de cette base d'information. Les données plus récentes (1960-1975) des expériences de pêche commerciale sont par contre utiles. Il n'existe pratiquement pas de données historiques sur la pêche sportive. La base de données biologiques consiste en la description des caractéristiques biologiques (croissance, structure, âge à maturité, etc.) de diverses populations, dont le nombre est somme toute limité, ainsi qu'à des informations sommaires sur la discrimination des stocks et les migrations marines.

Les travaux en cours réalisés par la MLCP, MAKIVIK et le MAPA s'inscrivent dans le cadre d'acquisition de connaissances pour l'aménagement concurremment à la mise en valeur. C'est notamment le cas du programme structuré pour le secteur est de la Baie d'Ungava et du programme similaire en implantation dans le secteur Kangiqsujuaq-Quaqtaq. Dans le premier cas, l'évaluation des niveaux de récolte par système est réalisée, ainsi que la caractérisation biologique des stocks et de l'expoitation au moyen du monitorage de la pêche commerciale d'hiver au filet maillant et la pêche commerciale d'été dans les barrières du comptage sur les systèmes expérimentaux. Les travaux réalisés sur les systèmes expérimentaux visent aussi la documentation et la détermination plus complète des caractéristiques biologiques de base, de la migration et du cycle vital de l'Omble chevalier du Nord québécois. Nous cherchons également à réaliser une validation indirecte des lectures d'âge. Dans le cadre du programme sur l'aménagement de l'habitat des rivières à Omble chevalier, en plus de la collecte d'informations pertinentes à l'évaluation du statut des stocks, des déterminations de niveaux de capture par système pour l'alimentation sont réalisées. Finalement, un système détaillé de suivi de l'exploitation et de monitorage biologique des captures sportives dans les pourvoiries a été mis sur pied.

STUDIES OF BENTHIC FISHES NEAR THE NUVUK ISLANDS IN NORTHEASTERN HUDSON BAY

J.M. Green

Department of Biology and Ocean Sciences Centre
Memorial University
St. John's, Newfoundland, A1B 3X9

During the summers of 1982, 1983, 1984, and 1988 we conducted field work on benthic marine fishes off the Nuvuk Islands in northeastern Hudson Bay. The initial work was intended to provide information on the relative and absolute abundances of benthic fishes preyed upon by black guillemots, and data on their spatial distribution. Data and samples were collected using scuba. In subsequent years we collected data on the feeding behaviour of these fishes and on temporal variation in their abundance.

While the relative abundance of each species remained fairly constant from year to year, marked variation in recruitment occurred between years. It is this variation in recruitment that may be of most interest to other biologists working in the Hudson Strait region. The fish species for which we have the best data, *Stichaeus punctatus*, has a pelagic larval stage. Our sampling indicates that recruitment is determined during the planktonic stage; but we have no idea what the important factor(s) or correlates are. Also we do not know how large a geographical area is influenced, although we suspect we are observing more than just a local phenomenon. We have not yet been able to carry out the kind of sampling necessary to answer the latter question. We believe our sampling technique is effective in assessing fish recruitment. *Stichaeus punctatus* could be a useful species to monitor yearly variation in ocean productivity in the region.

SEABIRD STUDIES PERFORMED BY CANADIAN WILDLIFE SERVICE (QUEBEC REGION) SINCE 1978 IN UNGAVA BAY A REVIEW OF WHAT WE LEARNED

G. Chapdelaine

Service canadien de la faune
Environment Canada
1141 Route de l'Eglise, C.P. 10100
Ste-Foy, Québec, G1V 4H5

In 1978, Canadian Wildlife Service (CWS), Quebec region executed an aerial survey to identify major sites used by eider ducks for breeding. Following the results of this aerial survey and additional information provided by the Makivik Society we identified 7 archipelagos to conduct detailed ground surveys aiming to estimate the total population nesting in Ungava Bay and the part of Hudson Strait between Ivujivik and Quaqtaq. We also collected information about the distribution and breeding of other species associated with the sea, like glaucous gull, herring gull, great black-backed gull and black guillemot. In 1981, 1982 and 1987 we investigated the breeding biology of the thick-billed murre at the two huge colonies on Akpatok Island. An estimate of the population, attendance patterns at the colonies, timing of breeding, breeding performance, feeding rates and chick growth are among the most important aspects studied. But many questions remain unanswered, especially about their prey, which probably explain the abundance of murres in the vicinity of Akpatok Island.

SEABIRDS: POPULATIONS, ECOLOGY AND ENERGY CONSUMPTION

A.J. Gaston

Canadian Wildlife Service
National Wildlife Research Centre
100 Gamelin Blvd.
Hull, Québec, K1A 0H3

The diversity of marine birds occurring in Hudson Strait is low compared to other arctic marine areas, but biomass standing stock is high in summer, especially in Ungava Bay and Western Hudson Strait. The eastern entrance to the

Strait, in the vicinity of Resolution Island, becomes important for surface-feeding seabirds in August and September, as post-breeding birds move in from other parts of the arctic.

In summer the marine bird community is dominated strongly by the thick-billed murre *Uria lomvia* which, with a population of about 2 million individuals, comprises more than 90% of standing stock. This species feeds in both coastal and offshore habitats, but generally in waters more than 40 m deep. Most feeding occurs between 20 and 50 m depth, but some birds dive as deep as 100 m. Its diet in summer includes both fish, particularly the arctic cod *Boreogadus saida*, and large zooplankton, mainly amphipods and mysids. Nearshore marine waters support significant populations of benthic-feeding common eiders *Somateria mollissima* and black guillemots *Cepphus grylle*, the former feeding largely on shellfish, the latter on benthic fishes, especially blennies.

Recent research, using doubly labelled water, has allowed us to estimate the energy requirements of the thick-billed murre population, and hence their total food consumption. Because of their small body size, relatively poor insulation and very high level of activity, seabirds consume much more energy daily than an equivalent mass of marine mammals. Thick-billed murres in Hudson Strait consume approximately 70,000 metric tons fresh weight over the entire season, equivalent to 0.36 g m^{-2}. Near to major colonies consumption per unit area is probably much higher and may have a significant impact on standing stocks of prey.

RESEARCH ON MARINE MAMMALS IN HUDSON STRAIT AND NORTHERN QUEBEC

T.G. Smith

Department of Fisheries and Oceans
Arctic Biological Station
555 boul. St-Pierre
Ste-Anne-de-Bellevue, Québec, H9X 3R4

The marine areas of Nouveau Québec provide extensive habitat for four species of Pinnipeds including the walrus and three different seals; several odontocetes or toothed whales of which the beluga is the most common; and several of the larger mystecete whales of which formerly the bowhead was common and abundant. Little systematic research on marine mammals was conducted in this large area prior to the James Bay and Northern Québec agreement in 1975. The first studies of a large scope were begun by Makivik Corporation and aimed at delimiting Inuit harvesting areas and establishing the catches of mammals in the hunting territories of the different coastal communities. Because of concerns about their vulnerability to over exploitation the first population assessment studies were aimed at the evaluation of the beluga stocks in Ungava Bay and eastern Hudson Bay. From this evolved an approach to beluga conservation involving voluntary quotas and interaction with DFO in the form of a working group made up of Anguvigak Wildlife Corporation, researchers and managers.

Work presently in progress include feeding ecology studies and documentation of seasonal condition of walruses, harp seals and bearded seals. Of a priority nature is the need to evaluate the stocks of belugas harvested in Ungava Bay where the population appears to be threatened. There also is a necessity to monitor the stock in eastern Hudson Bay and James Bay where the harvest is close to the calculated sustainable yield. Also of concern is our paucity of knowledge about the stocks of walruses in Hudson Strait and eastern Hudson Bay. While walrus hunting is reduced in Hudson Strait there appears to be building harvest pressure on the small stocks present in eastern Hudson Bay. A large effort will be required in collaboration with Central and Arctic Regions to evaluate the walrus population status.

Other species of pinnipeds in the area provide opportunities for gaining new information on their ecology and populations. Bearded seals which are most abundant in this area have been little studied anywhere and should be looked at especially with regard to their utilization of the high benthic biomass in several areas of Hudson Strait. Harp seals which occur in abundance during the summer and autumn in Hudson Strait are a much neglected arctic species and feed extensively in this area. Their increasing numbers and potential impact on southern fisheries during the winter months cannot be evaluated without a knowledge of their dependance on arctic resources. The habitat of ringed seals, which still play an important role as a food resource for many of the coastal communities should be delimited and evaluated. It is likely that there is a limited amount of suitable breeding habitat for this species especially in Hudson Strait and that some areas might have the potential of either being over exploited or disrupted by industrial development.

The larger cetaceans of the area are not at all known. Bowheads which were once abundant have all but been exterminated. Minke whales appear to be seasonally common in the eastern end of Hudson Strait. Other species such as the bottlenose whale are also known to occur in adjacent waters.

SIGNIFICANCE OF THE HUDSON STRAIT REGION AS A NEXUS IN THE MIGRATIONS OF THREE ARCTIC AND BOREAL MARINE MAMMAL ASSEMBLAGES

E.D. Mitchell[1] and R.R. Reeves[2]

Department of Fisheries and Oceans
[1] Arctic Biological Station, 555 boul. St-Pierre
Ste-Anne-de-Bellevue, Québec, H9X 3R4
[2] Department of Geography, McGill University
Montreal, Québec, H3A 2K6

The mouth of Hudson Strait is an important zoogeographic landmark for three different assemblages of cetaceans. It serves as a filter for these faunal assemblages, thus as a migratory corridor for some species and a barrier for others. Hudson Strait does not appear to have a discrete assemblage of resident marine mammal populations. The three assemblages are: Hudson Bay-Foxe Basin, Baffin Bay, and Northwestern North Atlantic Boreal.

The Hudson Bay-Foxe Basin assemblage is characterized by populations of *Balaena mysticetus*, *Delphinapterus leucas* and *Monodon monoceros*. These species are present year-round although in winter there is movement by some populations into or through Hudson Strait.

The Baffin Bay assemblage is also characterized by populations of *B. mysticetus*, *D. leucas* and *M. monoceros*. All of these populations undertake a winter migration out of Lancaster Sound into Baffin Bay and Davis Strait. The southern distributions of *B. mysticetus* and *M. monoceros* terminate on the west side of Davis Strait at or near the mouth of Hudson Strait. Few or none of the animals from the Baffin Bay populations of these two species enter Hudson Strait as far as is known. The area at or near the mouth of Hudson Strait thus may act as a barrier blocking their entry into Hudson Bay. The population of *D. leucas* that summers in the Lancaster Sound region is deflected eastward during its autumn southward migration well before reaching the mouth of Hudson Strait. For this population, the aggregate freeze-up and break-up pattern in Davis Strait may be decisive. Open water is found more reliably on the east than the west side of Davis Strait, possibly causing *D. leucas* (as well as at least some of the *M. monoceros* and *B. mysticetus*) to migrate eastwards upon clearing Lancaster Sound in the autumn.

The boreal assemblage of northwestern North Atlantic cetaceans is characterized by populations of *Balaenoptera musculus*, *Balaenoptera physalus*, *Balaenoptera borealis*, *Balaenoptera acutorostrata*, *Megaptera novaeangliae*, *Eubalaena glacialis*, *Physeter catodon*, *Hyperoodon ampullatus*, *Lagenorhynchus albirostris*, *Globicephala melas*, *Orcinus orca* and *Phocoena phocoena*. A few of these species migrate seasonally into Hudson Strait, but most are undocumented in Hudson Bay or Foxe Basin. For the following species, the northern limit of distribution on the west side of the northwestern North Atlantic is at or near the mouth of Hudson Strait: *B. musculus*, *B. physalus*, *M. novaeangliae*, *P. catodon*, *H. ampullatus*, *L. albirostris* and *G. melas*. The distributions of all these species extend much farther north along the west coast of Greenland. Hudson Strait and environs thus appear to act as a barrier to these species, blocking their access to Hudson Bay and Foxe Basin on the one hand, and blocking or deflecting their northward migration along the west side of Davis Strait, i.e. the east Baffin Island coast, on the other. Submarine canyons at the mouth of Hudson Strait, e.g. near Resolution Island, are areas of concentration of *P. catodon* and *H. ampullatus* on their migration along the Labrador Shelf, possibly to and from the banks off West Greenland (especially Fyllas Bank to Disko Bank). The mouth of Hudson Strait for these two species appears to be an attractant.

Hudson Strait thus appears to be a nexus for the three cetacean assemblages, where all come together in a relatively small region. Some of the species have specific prey preferences as known from stomach contents and direct observations of feeding in other areas. Given that prey availability and abundance affect cetacean distribution, some general hypotheses can be framed about the nature and abundance of trophic resources in the Strait. Only one boreal mysticete, *B. acutorostrata*, regularly enters the Strait whereas at least four others which occur regularly in the adjacent Labrador Sea and/or along the west coast of Greenland do not. The distribution of these five rorqual species suggests that copepods, euphausiids and possibly small fish such as capelin are not available in the Strait in sufficient local abundance to attract the large balaenopterids. The large, deep-diving teuthophages *P. catodon* and *H. ampullatus* regularly occur in the mouth of Hudson Strait, a distribution which suggests that squid and possibly herring-sized and larger fish are locally abundant there.

The above discussion excludes the pinnipeds, some of which are widely distributed but not highly migratory (e.g. *Phoca hispida, Phoca vitulina, Halichoerus grypus* and *Erignathus barbatus*); others of which are highly migratory but seem not to fit well into the faunal assemblages as set out above (e.g. *Phoca groenlandica* and *Cystophora cristata*). *Odobenus rosmarus* may be a significant exception, as there appear to be separate populations in Hudson Bay/Foxe Basin and Baffin Bay/Davis Strait, with some migratory movement into or through Hudson Strait as well as the possibility of some degree of residency in Hudson Strait and/or Ungava Bay. The feeding habits of walruses require the availability of large standing stocks of benthic molluscs. The regular presence of walruses in specific areas of Hudson Strait suggests the local availability of a large pelecypod resource.

SEASONAL DISTRIBUTION AND ABUNDANCE OF HUDSON STRAIT BELUGAS, NARWHALS AND WALRUS

P.R. Richard

Department of Fisheries and Oceans
Freshwater Institute
501 University Crescent
Winnipeg, Manitoba, R3T 2N6

Belugas, narwhals and walruses occupying Hudson Strait apparently all undergo some degree of seasonal movements to and from Hudson Bay or from S.E. Baffin Island coastal waters. Information on movements is mostly anecdotal but for narwhals and belugas aerial surveys have confirmed their winter presence in the Strait in numbers similar to summer concentrations in Hudson Bay. Walrus movements are less understood largely due to a lack of surveys.

Belugas occupying Hudson Strait in winter number 10,000 or more. Most of these animals leave Hudson Strait in the spring to occupy areas which cover almost the entire coast of Hudson Bay. Some belugas nevertheless remain in the Strait during the summer as shown by catch statistics from Hudson Strait communities.

Narwhals, on the other hand, are almost never hunted by Hudson Strait hunters. Yet, winter surveys have located a small recurring concentration of 600 or more at the eastern side of the Strait in winter. One narwhal was also seen at the western end of the Strait during one survey.

Walruses have been reported by several authors to undergo westward movements through Hudson Strait in spring and eastward movements in the fall. A few thousands are known to summer in northern Hudson Bay. There is little known about their winter distribution.

L'EXPLOITATION ET
LA GESTION DES RESSOURCES MARINES

M. Breton

MPO, Région du Québec
Division de la Répartition de la Resource
Gare Maritime Champlain
C.P. 15,500, 901 Cap Diamant
Québec, Québec, G1K 7Y7

Puisque la définition d'un programme de recherche doit non seulement prendre en considération les intérêts purement scientifiques mais aussi ceux d'ordre plus pratique, comme le développement des pêches et la conservation des ressources, il est nécessaire de connaître les priorités du secteur dit "gestion des ressources". L'exposé fera donc un survol du contexte politique de l'Arctique canadien, une revue de l'exploitation courante des ressources marines dans le Nord québécois - et plus spécifiquement dans le détroit d'Hudson -, ainsi que des diverses initiatives de développement des pêches dans les eaux marines périphériques. Les problèmes de gestion et de conservation des ressources et de leur habitat seront également identifiés. En conclusion, dans chacun des domaines abordés seront dégagées les orientations ou priorités actuelles.

COMITÉ D'ORGANISATION/ORGANIZING COMMITTEE

J.A. Percy (SBA/ABS) - Président/Chairman
E.G. Atkinson (SBA/ABS)
E.H. Grainger (SBA/ABS)
C. Hudon (SBA/ABS)
A.W. Mansfield (SBA/ABS)
T.G. Smith (SBA/ABS)
J.-C. Therriault (IML)

COMITÉ DIRECTEUR/STEERING COMMITTEE

J.A. Percy (SBA/ABS) - Président/Chairman
J.-C. Therriault (IML) - Océanographie biologique/Biological Oceanography
A. Sinclair (IML) - Division des pêches/Fisheries
C. Hudon (Halifax Research Laboratory) - Division des pêches/Fisheries
M. Kingsley (IML) - Mammifères marins/Marine Mammals
T.G. Smith (SBA/ABS) - Mammifères marins/Marine Mammals
Y. Gratton (IML) - Océanographie physique/Physical Oceanography
P. Larouche (IML) - Océanographie physique/Physical Oceanography

REMERCIEMENTS

Le Comité d'organisation remercie le personnel de la Station de biologie arctique qui a bien voulu prêter son aide et ses compétences. Leur travail dans la coulisse a grandement contribué à la bonne marche de l'atelier et à son succès général. M. Danis s'est chargé d'une grande partie de la correspondance avant la tenue de l'atelier et autres écritures administratives. J. Fife s'est occupé de la partie audiovisuelle et a fait fonction de projectionniste. D. Godard a participé aux inscriptions lors de l'atelier et s'est ensuite acquitté de l'énorme tâche de synthèse et de correction des différents articles du compte rendu de l'atelier. J. Lovrity s'est occupé de la représentation graphique et de la signalisation nécessaires à la tenue de l'atelier, a collaboré à la préparation des lieux et a établi de nombreuses cartes et figures nécesaires au compte rendu. S. Sylvestre s'est occupé des nombreux détails administratifs et financiers. Nous remercions sincèrement chacune de ces personnes. Nos remerciements s'adressent également aux nombreux réviseurs anonymes qui ont lu les versions préliminaires des différentes parties du compte rendu et proposé des améliorations.

ACKNOWLEDGEMENTS

The organizing committee is grateful for the capable and willing assistance of several members of the staff of the Arctic Biological Station. Their activities behind the scene contributed greatly to the smooth running and general success of the workshop. M. Danis handled much of the preworkshop correspondence and other paperwork. J. Fife looked after the audiovisual needs and served as projectionist. D. Godard assisted with registrations at the workshop and then took on the formidable task of synthesizing and correcting the various contributions to the workshop proceedings. J. Lovrity took care of the artwork and signs required at the workshop, assisted in preparing the facilities and drafted many of the maps and figures required for the proceedings. S. Sylvestre dealt with many of the administrative and financial details of the operation. To each of them our thanks. We are also grateful to several anonymous reviewers who read early drafts of various sections of the proceedings and suggested improvements.

PARTICIPANTS

M. Allard
Makivik Corporation
650 32nd Ave., 6th Floor
Lachine, Québec
H8T 1Y4
Tel. No.: (514) 634-8091
Fax. No.: (514) 634-8091

G. Atkinson
Arctic Biological Station
555 boul. St-Pierre
Ste-Anne-de-Bellevue, Québec
H9X 3R4
Tel. No. (514) 457-3660
Fax. No. (514) 457-6219

F. Axelsen
Ministère de l'Agriculture des Pêcheries
et de l'Alimentation
1665 Blvd. Wilfrid Hamel Ouest
Québec, Québec
G1N 3Y7
Tel. No. (418) 643-3848
Fax. No.

J. Boulva
Institut Maurice-Lamontagne
850, route de la Mer
C.P. 1000
Mont Joli, Québec
G5H 3Z4
Tel. No.: (418) 775-6555
Fax. No.: (418) 775-6542

M. Bradstreet
Long Point Bird Observatory
83 Brock St.
Vittoria, Ontario
N0E 1W0
Tel. No.: (519) 586-3531
Fax. No.:

M. Breton
MPO, Région du Québec
Gare Maritime Champlain
C.P. 15 500
901 Cap Diamant
Québec, Québec
G1K 7Y7
Tel. No.: (418) 648-5883
Fax. No.: (418) 648-4470

J.N. Bunch
Arctic Biological Station
555 boul. St-Pierre
Ste-Anne-de-Bellevue, Québec
H9X 3R4
Tel. No.: (514) 457-3660
Fax. No.: (514) 457-6219

R.R. Campbell
DFO Biological Sciences Directorate
Fisheries Research Branch
200 Kent Street
Ottawa, Ontario
K1A 0E6
Tel. No.: (613) 990-0287
Fax. No.: (613) 996-9055

G. Chantigny
MPO, Région du Québec
Division de la Répartition de la Ressource
Gare Maritime Champlain
C.P. 15,500
901 Cap Diamant
Québec, Québec
G1K 7Y7
Tel. No.: (418) 649-6196
Fax. No.: (418) 648-4470

G. Chapdelaine
Canadian Wildlife Service
Quebec region, Environment Canada
1141 route de l'Eglise
P.O. Box 10100
Ste-Foy, Québec
G1V 4H5
Tel. No.: (418) 649-6127
Fax. No.:

R. Clarke
Dept. of Fisheries and Oceans
Freshwater Institute
501 University Crescent
Winnipeg, Manitoba
R3T 2N6
Tel. No.: (204) 983-5182
Fax. No.: (204) 983-6285

R. Crawford
Dept. of Fisheries and Oceans
Freshwater Institute
501 University Crescent
Winnipeg, Manitoba
R3T 2N6
Tel. No.: (204) 983-5285
Fax. No.: (204) 983-6285

S. Demers
Institut Maurice-Lamontagne
850 route de la Mer
C.P. 1000
Mont Joli, Québec
G5H 3Z4
Tel. No.: (418) 775-6521
Fax. No.: (418) 775-6542

K.F. Drinkwater
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, N.S.
B2Y 4A2
Tel. No.: (902) 426-2650
Fax. No.: (902) 426-7827

M.J. Dunbar
Climate Research Group
Department of Meteorology
McGill University
805 Sherbrooke St. West
Montréal, Québec
H2A 2K6
Tel. No.: (514) 398-4407
Fax. No.: (514) 398-6115

A. Gaston
National Wildlife Research Centre
Canadian Wildlife Service
Environment Canada
100 Gamelin Blvd.
Hull, Québec
K1A 0H3
Tel. No.: (819) 997-6121
Fax. No.: (819) 953-6612

E.H. Grainger
Arctic Biological Station
555 boul. St-Pierre
Ste-Anne-de-Bellevue, Québec
H9X 3R4
Tel. No.: (514) 457-3660
Fax. No.: (514) 457-6219

J. Green
Memorial University of Newfoundland
Marine Sciences Research Laboratory
St. John's, Newfoundland
A1C 5S7
Tel. No.: (709) 737-7527
Fax. No.: (709) 737-4000

R. Harland
Arctic Biological Station
555 boul. St-Pierre
Ste-Anne-de-Bellevuee
H9X 3R4
Tel. No.: (514) 457-3660
Fax. No.: (514) 457-6219

S.I.C. Hsiao
Arctic Biological Station
555 boul. St-Pierre
Ste-Anne-de-Bellevue, Québec
H9X 3R4
Tel. No.: (514) 457-3660
Fax. No.: (514) 457-6219

C. Hudon
Halifax Research Laboratory
P.O. Box 550
Halifax, Nova Scotia
B3J 2S7
Tel. No.: (902) 426-5379
Fax. No.: (902) 426-2698

G. Ingram
Department of Meteorology
McGill University
805 Sherbrooke St. West
Montreal, Québec
H2A 2K6
Tel. No.: (514) 398-6071
Fax. No.: (514) 398-6115

S. Labonté
Institut Maurice-Lamontagne
850, route de la Mer
C.P. 1000
Mont Joli, Québec
G5H 3Z4
Tel. No.: (418) 775-6637
Fax. No.: (418) 775-6542

P. Larouche
Institut Maurice-Lamontagne
850, route de la Mer
C.P. 1000
Mont Joli, Québec
G5H 3Z4
Tel. No.: (418) 775-6569
Fax. No.: (418) 775-6542

L. Legendre
Université Laval
Dept. de Biologie
Secteur Ecologie Marine
Cité Universitaire
Pavillon Vachon
Ste. Foy, Québec
G1K 7P4
Tel. No.: (418) 656-5788
Fax. No.: (418) 656-5902

A.W. Mansfield
Arctic Biological Station
555 boul. St-Pierre
Ste-Anne-de-Bellevue, Québec
H9X 3R4
Tel. No.: (514) 457-3663
Fax. No.: (514) 457-6219

D. McAllister
Curator of Fishes
National Museum of Natural Sciences
Ichthyology Section
2378 Holly Lane
Ottawa, Ontario
K1A 0M8
Tel. No.: (613) 996-1755
Fax. No.: (613) 996-9915

E.D. Mitchell
Arctic Biological Station
555 boul. St-Pierre
Ste-Anne-de-Bellevue, Québec
H9X 3R4
Tel. No.: (514) 457-3663
Fax. No.: (514) 457-6219

R. Morin
Arctic Biological Station
555 boul. St-Pierre
Ste-Anne-de-Bellevue, Québec
H9X 3R4
Tel. No.: (514) 457-3663
Fax. No.: (514) 457-6219

D. Mudry
Environment Canada
Atmospheric Environment
Ice Centre
373 Sussex Drive
Block E
Ottawa, Ontario
K1A 0H3
Tel. No.: (613) 996-4214
Fax. No.: (613) 563-8483

D. Nakashima
Makivik Corporation
650 32nd Ave., 6th Floor
Lachine, Québec
H8T 1Y4
Tel. No.: (514) 634-8091
Fax. No.: (514) 634-8091

J.A. Percy
Arctic Biological Station
Dept. of Fisheries and Oceans
555 boul. St-Pierre
Ste-Anne-de-Bellevue, Québec
H9X 3R4
Tel. No.: (514) 457-3660
Fax. No.: (514) 457-6219

D. Pike
Dept. of Fisheries and Oceans,
Arctic Operations Directorate,
Eastern Area
P.O. Box 358
Iqaluit, N.W.T.
X0A 0H0
Tel. No.: (819) 979-6274
Fax. No.: (819) 979-4539

D. Ponton
Univ. Laval, Dept. de Biologie
Cité Universitaire
Pavillon Vachon
Ste-Foy, Québec
G1K 7P4
Tel. No.: (418) 656-2562
Fax. No.:

M. Poulin
Botany Division
National Herbarium of Canada
National Museum of Natural
Sciences
1505 Laperrière Ave.
Ottawa, Ontario
K1Z 7T1
Tel. No.: (613) 990-6454
Fax. No.: (613) 952-9693

G. Power
Dept. of Biology
University of Waterloo
Waterloo, Ontario
N2L 3G1
Tel. No.: (519) 885-1211
Fax. No.: (519) 888-4521

R. Reeves
Arctic Biological Station
555 boul. St-Pierre
Ste-Anne-de-Bellevue, Québec
H9X 3R4
Tel. No.: (514) 457-3663
Fax. No.: (514) 457-6219

P. Richard
Dept. of Fisheries and Oceans
Freshwater Institute
501 University Crescent
Winnipeg, Manitoba
R3T 2N6
Tel. No.: (204) 983-5130
Fax. No.: (204) 983-6285

J. Roff
University of Guelph
Department of Biology
Guelph, Ontario
N1G 2W1
Tel. No.: (519) 824-4120
Fax. No.: (519) 836-2063

L. Roy
Gouvernement du Québec
Ministère du Loisir, de la
Chasse et de la Pêche
Direction régionale du Nouveau-
Québec
1995 Charest Ouest
Ste-Foy, Québec
G1N 4H9
Tel. No.: (418) 643-6662
Fax. No.: (418) 643-2057

R. J. Runge
Institut Maurice-Lamontagne
850, route de la Mer
C.P. 1000
Mont Joli, Québec
G5H 3Z4
Tel. No.: (418) 775-6767
Fax. No.: (418) 775-6542

A. Sinclair
Institut Maurice-Lamontagne
850, route de la Mer
C.P. 1000
Mont Joli, Québec
G5H 3Z4
Tel. No.: (418) 775-6643
Fax. No.: (418) 775-6542

T.G. Smith
Arctic Biological Station
555 boul. St-Pierre
Ste-Anne-de-Bellevue, Québec
H9X 3R4
Tel. No.: (514) 457-3663
Fax. No.: (514) 457-6219

B. Sundby
Director of Physical and
Chemical Sciences
Institut Maurice-Lamontagne
850, route de la Mer
Mont Joli, Québec
G5H 3Z4
Tel. No.: (418) 775-6703
Fax. No.: (418) 775-6542

C. Taggart
Dalhousie University
Department of Oceanography
Halifax, N.S.
B3H 4J1
Tel. No.: (902) 424-8894
Fax. No.: (902) 424-2319

J.-C. Therriault
Institut Maurice-Lamontagne
850 route de la Mer
C.P. 1000
Mont Joli, Québec
G5H 3Z4
Tel. No.: (418) 775-6595
Fax. No.: (418) 775-6542

H.E. Welch
Dept. of Fisheries and Oceans
Freshwater Institute
501 University Crescent
Winnipeg, Manitoba
R3T 2N6
Tel. No.: (204) 983-5132
Fax. No.: (204) 983-6285